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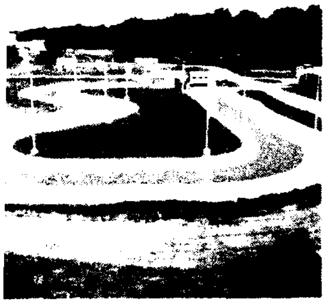

HYDRAULICS LABORATORY

FLOOD CONTROL STRUCTURES RESEARCH PROGRAM

TECHNICAL REPORT HL-92-5

RIPRAP STABILITY: STUDIES IN NEAR-PROTOTYPE SIZE LABORATORY CHANNEL

by

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Riprap stability tests were conducted in the large test channel at the US Army Engineer Waterways Experiment Station to develop improved design guidance for riprap subjected to flow-induced forces. Rock size in bends, side slope effects, flow duration effects, and characteristic particle size were addressed in the investigation. Limited tests were conducted to evaluate the effects of riprap thickness, stability of rounded rock, riprap packing effects, and effects of filter type on stability. The procedure is based on local depth-averaged velocity, and extensive velocity measurements were conducted throughout the test channel.

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PREFACE

The study described herein was performed by personnel of the Hydraulics Laboratory, US Army Engineer Waterways Experiment Station (WES), during the period 1987-1991. It was sponsored by Headquarters, US Army Corps of Engineers (HQUSACE), as part of the Flood Control Structures Research Program under Civil Works Investigation Work Unit 32541, "Riprap Design and Cost Reduction: Studies in Near Prototype Size Laboratory Channel." HQUSACE Program Monitor was Mr. Tom Munsey.

This study was accomplished under the direction of Messrs. F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory; R. A. Sager, Assistant Chief of the Hydraulics Laboratory; and G. A. Pickering, Chief of the Hydraulic Structures Division, Hydraulics Laboratory. The tests were conducted by Dr. S. T. Maynord, project engineer, and Messrs. D. M. White and J. T. Hilbun, Spillways and Channels Branch, Hydraulic Structures Division, under the direct supervision of Mr. N. R. Oswalt, Chief of the Spillways and Channels Branch. This report was written by Dr. Maynord and edited by Mrs. Marsha Gay, Information Technology Laboratory, WES.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

CONTENTS

	Page
PREFACE	1
CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	4
Background	4
Purpose and Scope	6
PART II: BASIC EQUATIONS	7
PART III: EXPERIMENTAL INVESTIGATION	9
Riprap Characteristics	9
Test Procedure	9
Data Presentation	10
PART IV: ANALYSIS AND RESULTS	12
Characteristic Particle Size	12
Side Slope Angle Effects	14
Flow Duration Effects on Riprap Stability	14
Characteristic Velocity for Side Slopes	16
Riprap Size in Channel Bends	17
Bottom Riprap Tests	19
Riprap Thickness Effects	20
Stability of Rounded Rock	21
Effects of Riprap Packing	22
Effects of Filter Type	22
PART V: SUMMARY AND CONCLUSION	24
REFERENCES	25
TABLES 1-14	
PLATES 1-18	
APPENDIX A: VELOCITIES	A1
APPENDIX B: DESCRIPTION OF ROCK MOVEMENT AND FAILURE	B1
APPENDIX C: NOTATION	C1

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
degrees Fahrenheit	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
inches	2.54	centimetres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre

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* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

RIPRAP STABILITY: STUDIES IN NEAR-PROTOTYPE SIZE LABORATORY CHANNEL

PART I: INTRODUCTION

Background

1. The US Army Corps of Engineers spends large amounts on riprap channel protection each year for the project purposes of flood control and navigation. In an attempt to reduce both initial and maintenance costs, research has been underway for a number of years to develop improved guidance for design of riprap. Riprap design guidance must be applicable to a wide range of channel cross sections and alignments, hydraulic conditions, riprap gradations, thicknesses, and shapes. However, past experience has shown that any guidance that is not relatively easy to apply will most likely be discarded in favor of a simple table relating rock size to velocity. Consequently, this research has attempted to take the complex problem of riprap stability and define it in parameters that are easy to apply. The design procedures developed in this research program have been incorporated into Engineer Manual (EM) 1110-2-1601 (Headquarters, US Army Corps of Engineers 1991).

2. The first step in achieving ease of application was to discard the traditional tractive force procedure and use velocity to define the forces imposed on the riprap. While tractive force is preferred because it attempts to define the forces on the channel boundary, it has not been widely adopted by engineers involved in riprap design. Furthermore, determining tractive force in complex geometries or in areas of high relative roughness or significant secondary currents is difficult because the logarithmic relationship between tractive force and depth-averaged velocity is not applicable. Wave stability equations have taken a similar approach; wave height is used instead of a force on the boundary.

3. The second step in achieving ease of application is to accept that some factors are not yet understood and that their effects are lumped into the empirical stability coefficients. For example, riprap gradation affects stability in many ways including the following:

a. How significant is size segregation when using a gradation having a wide range in sizes.

b. In gradations having a wide range of sizes, are small particles sheltered by larger particles or are they more easily washed away due to turbulence in the wake of the larger particles?

c. What is the impact of gradation on particle interlock?

While each of these are important factors, they were not addressed individually in this study. This study accepts that the factors affecting gradation are complex, and empirical stability coefficients that combine many of these factors are determined for a range of gradation uniformity.

4. The initial version of this velocity-based design procedure was presented in Maynord 1988 and Maynord, Ruff, and Abt 1989 and was based on a large number of flume tests conducted at Colorado State University (CSU), Fort Collins, CO, and the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Local depth-averaged velocity is used as the characteristic velocity and D_{30} is used to represent gradation effects in this design procedure. The primary limitation of that study was lack of systematic data in channel bends and on various channel side slopes. To address bend and side slope effects, the Riprap Test Facility (RTF) was constructed at WES. The RTF (Figure 1) is a recirculating outdoor open channel facility having a length of

Figure 1. Riprap Test Facility

780 ft*, four bendways, and two constant-speed and two variable-speed pumps that supply a discharge Q of 0-200 cfs. The RTF was initially molded to a trapezoidal cross section having 1V:2H side slopes, 12-ft bottom width, 0.2 percent bottom slope, and 2.5-in.-thick riprap having a maximum stone size of 2.1 in. on both the bottom and side slopes. The channel schematic is shown in Plate 1.

Purpose and Scope

5. The objectives of this study are to address the following limitations of the velocity-based procedure presented in Maynord, Ruff, and Abt (1989):

a. What is the effect of using a single particle size (D_{30}) to characterize a gradation?

b. What is the effect of side slope angle ranging from 1V:3H to 1V:1.5H?

c. What is the influence of flow duration on riprap stability?

d. What is the characteristic velocity for side slopes in both straight and curved channels?

e. What is the rock size required on the outer bank of channel bends?

In addition to these objectives, limited tests were conducted to compare bottom riprap stability in the RTF to CSU results, to determine the impacts of riprap thickness, to evaluate the stability of rounded rock, to determine if packing riprap improves stability, and to determine the impacts of a granular filter versus a fabric filter.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 3.

PART II: BASIC EQUATIONS

6. The basic equation developed by Neill (1967) and presented in Maynord (1988) is

$$\frac{D_r}{d} = C\left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{1/2} \frac{V}{\sqrt{gd}}\right]^{2.5} \tag{1}$$

where

D_r = characteristic particle size*

d = local flow depth

C = coefficient

γ_w = unit weight of water

γ_s = unit weight of stone

V = local depth-averaged flow velocity

g = gravitational acceleration

Equation 1 can be developed from the following equations:

$$\tau_b = \gamma_w\, d\, S \tag{2}$$

$$\tau_c = C_{sm}(\gamma_s - \gamma_w)D_r \tag{3}$$

$$V = \frac{1.49}{n} d^{2/3} S^{1/2} \tag{4}$$

$$n = C\, D_r^{1/6} \tag{5}$$

$$C_{sm} = C(D_r/d)^{2/15} \tag{6}$$

where

τ_b = bed shear stress

---

* For convenience, symbols and unusual abbreviations are listed and defined in the Notation (Appendix C).

S = energy slope

τ_c = critical tractive force for given particle size on horizontal bed

C_{sm} = modified Shields coefficient

n = Manning's roughness coefficient

The modified Shields coefficient (Equation 6) is conceptually in agreement with findings of several investigators (Maynord 1988) showing variation of Shields coefficient with relative roughness. Equation 1 lumps the effects of velocity profile, turbulence, and Shields stability coefficient into a single equation. The disadvantage of this approach is that different velocity profiles and Shields relationships cannot be easily inserted to make this a more general procedure such as that proposed by Pilarczyk (1990). The advantage of this approach is that stability coefficients can be readily determined from both laboratory and field data without having to address the interrelated and complex problems of velocity profile, Shields coefficient, and turbulence level. The effects of these factors are combined into the empirical stability coefficients.

7. Using tractive force concepts, the tractive force ratio for side slope K is

$$K = \frac{\tau_s}{\tau_c} \tag{7}$$

where τ_s is the critical tractive force on the side slope. Combining Equations 2-7 results in the following equation, presented in Permanent International Association of Navigation Congresses (1987) and attributed to Pilarczyk:

$$\frac{D_r}{d} = C\left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{1/2} \frac{V}{\sqrt{Kgd}}\right]^{2.5} \tag{8}$$

Equation 8 will be the basic equation used throughout this investigation. From Maynord (1988) a characteristic particle size of D_{30} and a value of C of 0.30 were determined for bottom riprap in straight channels placed to a thickness of $1D_{100}$.

PART III: EXPERIMENTAL INVESTIGATION

Riprap Characteristics

8. The riprap gradations used in this investigation are shown in Table 1 and Plates 2-7. The shape characteristics of the rock used in gradations 2-9 are shown in Table 2. To determine stone dimensions L and b, consider that the stone has a long axis, an intermediate axis, and a short axis. Dimension L is the maximum length of the stone, which defines the long axis of the stone. The intermediate axis is defined by the maximum width of the stone. The remaining axis, which is perpendicular to the other two axes, is the short axis. Dimension b is the maximum stone dimension parallel to the short axis. Results of angle of repose tests for angular rock as a function of revetment height are shown in Plate 8 along with results from Ulrich (1987) and Maynord (1988). These tests were conducted with a hinged plate as described in Ulrich (1987) and Maynord (1988).

Test Procedure

9. The original gradation 1 was placed to a thickness of 1.25 D_{100} throughout the facility. Side slope stability testing of gradations 2-11 took place in bendways 1 and 3 (bendway 1 is upstream). The gradation to be tested was placed from near the upstream end of the bend to the beginning of the next bend. The riprap was placed on the outer bank side slope and on the channel bottom for a distance of 2 ft from the toe of the outer bank slope. The remainder of the cross section was left covered with the original gradation 1. Unless noted, riprap was placed on a nonwoven filter fabric. Riprap placement in the RTF was intended to simulate placement in the prototype in which the riprap is dumped close to its final position with a minimum of spreading. No packing or tamping was permitted unless noted. After placement, the riprap was painted in horizontal strips of different color to facilitate observation of movement as shown in Figure 2 and Plate 9. For side slope tests with slopes of 1V:1.5H and 1V:3H, the outer bank of bendway 1 was remolded to the desired bank slope keeping the toe of slope in the same location as in the 1V:2H tests. Failure criteria was incipient failure (Maynord 1988), which is the flow conditions at which the filter fabric begins to be exposed after

Figure 2. Riprap Test Facility bendway 1, looking downstream

running a constant discharge for 72 hr (see section "Flow Duration Effects on Riprap Stability" for basis of 72-hr test).

Data Presentation

10. Detailed velocity measurements were taken in the RTF to document flow conditions for both stable and failure conditions. Velocities were collected with a two-dimensional electromagnetic meter in the early tests and a one-dimensional pitot tube in all subsequent tests. These velocity measurements were taken to determine the distribution of depth-averaged velocity. Upon completion of construction of the RTF, the bed and banks were covered with gradation 1. Detailed velocities were taken from sta 1+78 to 6+25 for discharges of 49, 101, and 150 cfs with the two-dimensional electromagnetic velocity meter. Depth-averaged velocities were determined from the detailed velocities and were converted to a dimensionless value by dividing by the cross-sectional average velocity at that location. The dimensionless

depth-averaged velocities for the three discharges are shown in Plates A1-A9. No riprap failure was observed for any of the three discharges with gradation 1.

11. Stability testing of gradations 2 through 11 required documentation of the velocities over the outer bank slope for discharges that resulted in stable and failure conditions. Tables 3, 4, 5, and 6 summarize test conditions for stability tests of gradations 2-11 and provide plate numbers in Appendix A for the measured velocities for side slopes of 1V:2H, 1V:3H, 1V:1.5H, and bottom riprap, respectively. Test numbers in the side slope velocity plots in Appendix A give the discharge first, then the cotangent of the side slope, then the stone type (S for crushed stone, RS for rounded stone), then the station where the velocities were measured, and finally the gradation number. For example, test 502RS602.G10 was 50 cfs, 1V:2H side slope, rounded stone, sta 602, and gradation 10. Appendix B provides details of observed rock movement and failure for each test.

PART IV: ANALYSIS AND RESULTS

Characteristic Particle Size

12. Maynord (1988), Abt et al. (1988), Ahmed (1987), and Anderson, Paintal, and Davenport (1968) conducted riprap stability tests that showed that for riprap gradations having the same D_{50}, the uniform gradations are more stable than the nonuniform gradations. To make the nonuniform gradations as stable as the uniform gradations requires a characteristic size less than D_{50}. Maynord (1988) found a characteristic size of D_{30} based on stability tests of a range of gradations from uniform to nonuniform for thickness equal to the maximum stone size. Einstein (1942), Schoklitsch (1962), California Division of Highways (1970), Peterka (1958), and Shen and Lu (1983) also used characteristic particle sizes of D_{30} to D_{40} in stability equations. Figure 3 shows three riprap gradations having varying degrees of uniformity. Based on Maynord (1988), each gradation would have the same stability and the uniform gradation would require the least volume of rock because thickness is equal to the maximum stone size. However, consider the three gradations shown in Figure 4, which have the same size distribution below D_{30}. If the riprap is placed to a thickness of the maximum stone size, use of D_{30} would indicate each gradation would have the same stability. However, it is likely that the increased thickness for the nonuniform gradations would increase stability compared to the uniform gradation only because the gradation below D_{30} is the same. Various particle size ratios and combinations were evaluated to find one that preserves the estimate of D_{30} yet provides an increase in stability for nonuniform gradations over uniform gradations in cases like that shown in Figure 4. The following equation for characteristic particle size D_r

$$D_r = \sqrt[3]{D_{15}^2 \, D_{85}} \qquad (9)$$

provides D_r almost identical to D_{30} for the gradations used in Maynord (1988) that were used to determine D_{30} as the characteristic size. For the gradations used in this report, Equation 9 gives D_r averaging only 4 percent greater than D_{30}. Equation 9 also provides different stability for comparing gradations like those shown in Figure 4. Equation 9 is considered an

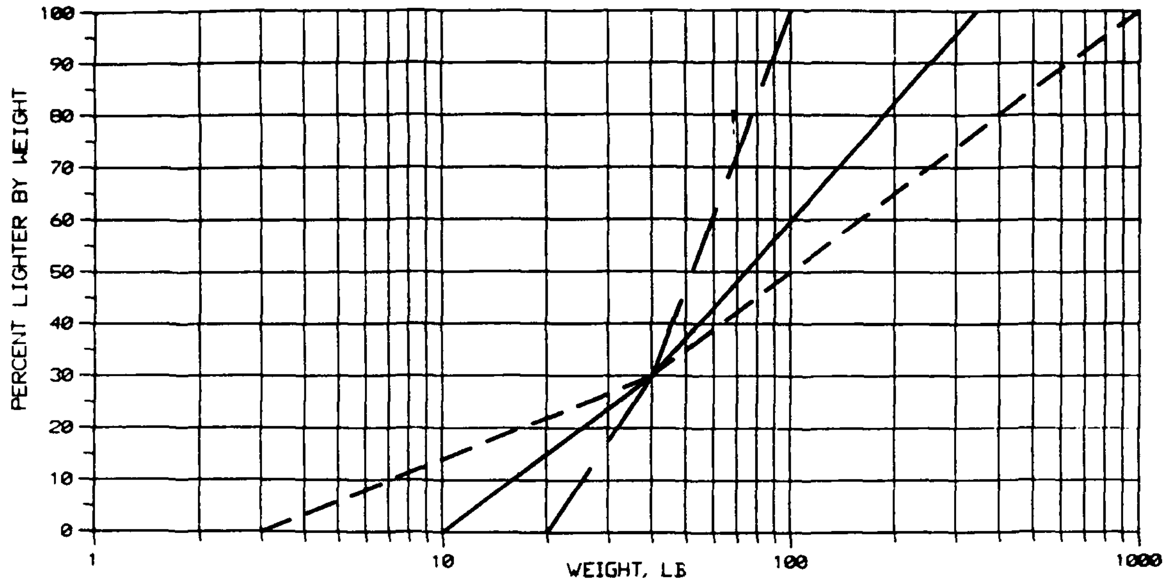

Figure 3. Gradations having same D_{30} with different size distribution below D_{30}

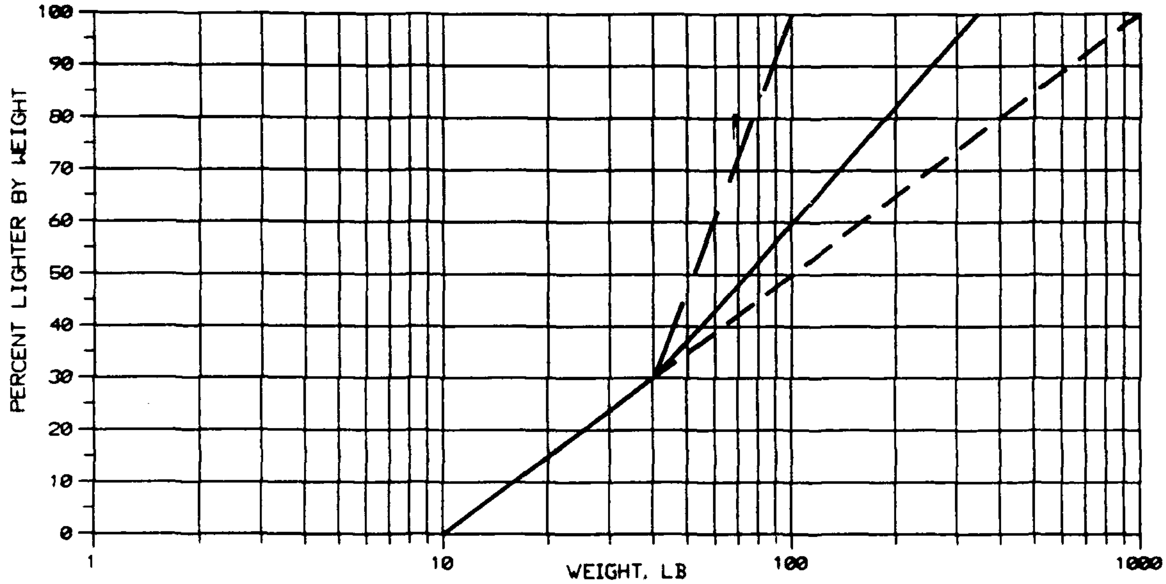

Figure 4. Gradations having same D_{30} with same size distribution below D_{30}

improvement over the use of D_{30} as the characteristic size and should be used if significantly different from D_{30}. D_{30} is used herein as the characteristic size due to the similarity of D_r and D_{30}.

Side Slope Angle Effects

13. Systematic tests were reported in Maynord (1988) on the variation of tractive force ratio K with side slope angle θ , and results are shown in Plate 10. Also shown is the tractive force approach given by Carter, Carlson, and Lane (1953) and the relationship of Ulrich (1987). For side slopes in channel bends, Brooks (1963) demonstrates the importance of secondary currents on the K ratio. The angle of secondary currents remains poorly defined, and their equation for K is not used herein. The experimentally derived values for K from Maynord (1988) are in fair agreement with the results of Ulrich (1987) and are adopted for this investigation. While revetments should not be constructed near the angle of repose, this parameter is not the typical 40 deg used by many (Plate 8); and repose angle will not be used in the side slope analysis.

Flow Duration Effects on Riprap Stability

14. One of the difficult issues in riprap design is the influence of time or flow duration on stability. One way to handle time is to treat riprap design as a transport problem and define some maximum allowable transport rate. This approach may be acceptable when there are multiple layers of material but becomes questionable when a thin veneer of material is used, which is frequently the case in riprap revetments. Another drawback to treating this as a transport problem, as discussed in Part I, is the necessity for ease of application. A further drawback is determining how the various hydrographs over a given project life add together to form a total time for use in design. Consequently, most riprap design procedures simply specify stability coefficients that are intended to apply to extremely long flow durations. Defining flow conditions at which significant movement ceases has been termed practical equilibrium. The following analysis will determine if a practical equilibrium approach is justified for this study by conducting tests to evaluate the influence of time on stability. Using the dimensional analysis given in

Maynord, Ruff, and Abt (1989) but adding time to the pertinent variables results in

$$\frac{D}{d} = f\left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{1/2} \frac{V}{\sqrt{gd}}, \frac{Vt}{d}\right] \qquad (10)$$

The practical equilibrium concept can be used if a value of Vt/d can be found above which time t has no significant effect on stability.

15. Testing was conducted with gradation 2 to test flow duration effects with results as follows:

Q cfs	V fps	d ft	t hr	Result*	$Vt/d \times 10^5$
50	3.21	1.17	72	S	7.1
60	3.40	1.26	72	S	7.0
70	3.60	1.42	15	S	1.4
70	3.60	1.42	16	F	1.5
70	3.60	1.42	24.5	F	2.2
80	3.76	1.53	12	F	1.1
80	3.76	1.53	3.5	F	0.3

* S = stable; F = failure.

The velocity and depth are at a point 20 percent up the side slope from the toe. These results, plotted in Figure 5, indicate a dependence of the failure

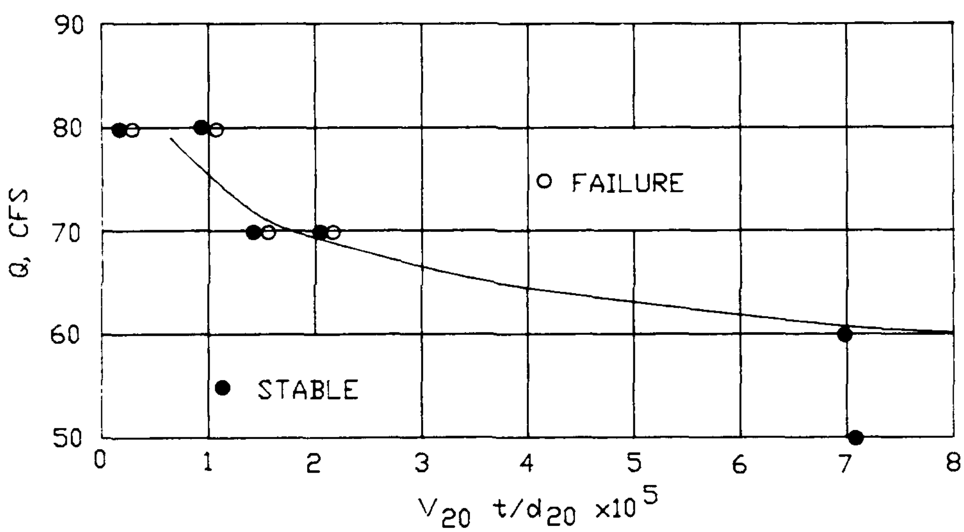

Figure 5. $V_{20}t/d_{20} \times 10^5$ versus discharge

discharge on the time parameter. As test duration goes up, failure discharge goes down, which is the expected trend. For the gradation 2 tests, use of a test duration shorter than 16 hr would not have permitted observing failure at 70 cfs. The dependance on Vt/d becomes minor for values of Vt/d greater than 3-4 $\times 10^5$ for the failure criteria used herein.

16. The CSU bottom riprap tests given in Maynord (1988) had an average Vt/d of 2×10^5 and resulted in an incipient failure coefficient of 0.30 for bottom riprap in a straight channel. Bottom riprap tests (paragraph 24) conducted in the straight channel portion of the RTF for Vt/d of 4×10^5 had an incipient failure coefficient of 0.32, which may not be significantly different from the CSU tests. Based on the gradation 2 tests and on the comparison of bottom riprap in CSU and RTF testing, a minimum Vt/d of 4×10^5 is proposed for the failure criteria used herein and riprap thickness of $1D_{100}$. At $Vt/d > 4 \times 10^5$, time plays a minor role in determining failure. All stability tests were conducted either until failure or for 72 hr, which resulted in Vt/d of 4-7 $\times 10^5$.

17. A question that must be answered is are there a significant number of prototype installations having $Vt/d < 4 \times 10^5$ that would benefit from a design procedure that would reduce the rock size for short-duration flows? Consider a rather flashy stream having a design velocity of 10 fps and a design depth of 15 ft that occurs for one day per year over a design life of 25 years. The resulting $Vt/d = 1.4 \times 10^6$ demonstrates that even rather flashy streams have total time parameters (Vt/d) greater than the limit (4×10^5) determined for minor time dependance.

Characteristic Velocity for Side Slopes

18. In developing a velocity-based design procedure, it is not sufficient to use a side slope velocity or bank velocity unless a fixed location is specified. This is because the velocity varies significantly with distance from the waterline. In the initial development of the velocity-based design procedure (Maynord 1988; Maynord, Ruff, and Abt 1989), a characteristic velocity of the depth-averaged velocity over the toe of the slope was used in the design of side slope riprap. For straight channels, 1V:2H side slope ($K = 0.88$), and riprap thickness of $1D_{100}$, Equation 8 for incipient failure for data presented in Maynord (1988) becomes

$$\frac{D_{30}}{d} = 0.21 \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{1/2} \frac{V}{\sqrt{Kgd}}\right]^{2.5} \tag{11}$$

based on depth-averaged velocity and depth over the toe of the slope. Since the coefficient in Equation 11 is less than the coefficient for bottom riprap in straight channels, it is apparent that the velocity and depth over the toe are not characteristic of the side slope in straight channels. Using the CSU 1V:2H side slope velocity and riprap stability data (Tables 7 and 8 and Plate 11), a characteristic velocity and depth were found at 20 percent up the slope from the toe that resulted in a coefficient of 0.30 in Equation 8. Looking back at the straight channel shear distribution studies referenced in Chow (1959), the maximum shear on the side slope occurred 20-30 percent up from the toe for a side slope of 1V:1.5H. Failures in the straight channel tests at CSU were up on the side slopes and consistent with the location of maximum shear given in Chow (1959). Comparing a point on the side slope 20 percent up the slope from the toe, the depth-averaged velocity in the CSU straight channel over the 20 percent point is about 85 percent of the depth-averaged velocity over the toe of the slope for a 1V:2H side slope. In the bends of the RTF, the depth-averaged velocity over the 20 percent point is about 100 percent of the depth-averaged velocity over the toe of the slope. Thus, the velocity distribution over the side slope is significantly different in straight and curved channels. Failures in the RTF channel bends were between 20 and 50 percent of the slope distance from the toe as described in Appendix B. These factors lead to the conclusion that conditions at the toe are not representative of the critical area of the channel side slope for both straight and curved channels. The velocity and depth at 20 percent up the slope from the toe are adopted as the characteristic values for both straight and curved channels.

Riprap Size in Channel Bends

19. Stability tests were conducted in bendways 1 and 3 for side slopes of 1V:2H, 1V:3H, and 1V:1.5H. Results are evaluated in the following paragraphs using Equation 8 with K values from Maynord (1988) shown in Plate 10

and depth-averaged velocity and depth at a point 20 percent up the slope from the toe.

20. From channel bends 1 and 3 in the RTF, a 1V:2H side slope (K = 0.88 in Equation 8), and riprap thickness of $1D_{100}$, the stability coefficient C in Equation 8 for incipient failure is 0.36 using depth-averaged velocity and depth at a point 20 percent up the slope from the toe. Equation 8 with C = 0.36 is plotted in Plate 12 with stability data from gradations 2, 4, 6, and 8 (Table 9). The measured velocities and depths shown in Appendix A were used to develop a rating curve for velocity and depth at sta 5+78 in bend 3. This rating curve (Plate 13) was used to determine velocity and depth for two of the stability tests in which measurements were not conducted. Most of the failures and the highest velocities were found at sta 3+06 and 5+78 in bends 1 and 3, respectively.

21. From channel bend 1 in the RTF, a 1V:3H side slope (K = 0.98), and riprap thickness of $1D_{100}$, stability tests were conducted for gradations 6 and 8. Results are shown in Table 10. Gradation 6 resulted in a stability coefficient C of 0.36 to 0.37, which is consistent with 1V:2H results using Equation 8. Gradation 8 resulted in a stability coefficient of about 0.26, which is considerably less than gradation 6 and results from the 1V:2H side slope tests. Past experience with stability tests have shown that uniform ripraps such as gradations 2, 3, and 6 give consistent results. Highly non-uniform ripraps like gradation 8 often give significant variation in the results. Although it was not apparent when inspecting the test channel, there may have been an excess of large particles at the critical point in the first bend or simply a lack of size segregation in the critical areas. Highly non-uniform ripraps have a significant capacity to "heal" themselves due to upslope material moving into locally weak areas. Wittler and Abt (1990) report that uniform and nonuniform ripraps fail in different ways. Uniform ripraps tend to fail without a lot of prior movement of particles whereas nonuniform ripraps tend to fail only after a significant amount of particle movement or rearrangement.

22. From channel bend 1 in the RTF, a 1V:1.5H side slope (K = 0.72), and riprap thickness of $1D_{100}$, stability tests were conducted for gradations 2 and 4. Results are shown in Table 11. Gradation 2 resulted in a stability coefficient in the range of 0.35 to 0.38, which is consistent with the results from the 1V:2H side slope and gradation 6 on the 1V:3H side slope.

Gradation 4 resulted in a stability coefficient of 0.29 to 0.32. Gradation 4, like gradation 8, is a nonuniform gradation, which had a significant amount of movement prior to failure.

23. The difference between coefficients for riprap in a straight channel ($C = 0.30$) and bend riprap ($C = 0.36$) is likely due to the secondary currents present in the channel bend that alter the velocity distribution. The secondary currents move the higher velocities near the channel boundary (Meckel 1978) and/or cause the resultant drag force to be skewed down the side slope (Brooks 1963). The change in velocity profile was evident in profiles measured in bendway 1 with the 1V:3H side slope. Velocity profiles were determined normal to the side slope at a point 20 percent up the side slope from the toe at sta 2+81 and 3+06. Results are compared to straight channel flume velocity profiles in Plates 14 and 15. V_y is the velocity at distance y above the bottom. The increased velocities at the channel bottom are particularly evident at sta 2+81. The magnitude of the secondary currents is primarily dependant on the degree of curvature, which is often described by the ratio of center-line radius to channel width. Plate 16 presents a method for varying the stability coefficient in Equation 8 as a function of R/W to account for the change in velocity profile normal to the boundary. R is the center-line radius of the bend and W is the water-surface width. Plate 16 is supported by RTF results for $R/W = 2.5$ having $C = 0.36$ and Maynord (1988) results for straight channels (R/W = large) having $C = 0.30$. What is missing are data at various R/W to define the value of R/W at which a channel is essentially straight. A conservative value of $R/W = 25$ was chosen as the breakpoint for no curvature effect on the velocity profile. This approach assumes fully developed bend flow since bend angle is not included in the analysis.

Bottom Riprap Tests

24. Bottom riprap tests were conducted in the straight reach upstream of bendway 1 as shown in Plate 17. These tests were conducted to obtain data to compare to the CSU straight flume data used in Maynord (1988) and to obtain data regarding run time effects on riprap stability. Test results are shown in Table 6. Failure occurred at a stability coefficient in Equation 8 of $C = 0.32$.

Riprap Thickness Effects

25. Riprap is normally placed to a minimum thickness of $1D_{100}$ or $1.5D_{50}$, whichever is greater. Gradations having D_{85}/D_{15} greater than about 2 have a greater thickness based on the maximum stone size, D_{100}. Gradations having D_{85}/D_{15} less than 2 have a greater thickness based on $1.5D_{50}$.

26. Gradations 3 (angular) and 11 (rounded) were gradations having D_{85}/D_{15} of 1.2-1.3, but they were tested with a thickness of $1D_{100}$, which was less than $1.5D_{50}$. Gradation 3 resulted in a stability coefficient of 0.43 in Equation 8, which is about 20 percent greater (which means less stable) than gradations shown in Plate 12, which meet both the $1D_{100}$ and $1.5D_{50}$ requirements. Similarly for rounded stone, gradation 11 resulted in a stability coefficient in Equation 8 of 0.47 compared to rounded gradation 10, which met both thick-ness requirements and had a stability of 0.40. For both angular and rounded stone, an approximate 20 percent increase in stone size is required when the thickness requirement of $1.5D_{50}$ is not met. However, the resulting difference in blanket thickness between the required $1.5D_{50}$ and the 20 percent increase in D_{100} is small. For example, gradation 3 placed to a thickness of $1.5D_{50}$ would be 1.5(0.88 in.) = 1.3 in. rather than the 1.0 in. that was tested. If placed to a thickness not meeting the $1.5D_{50}$ criterion but equal to $1D_{100}$, rock size must be increased by 20 percent. This criterion resulted in a thickness of 1.2 in., which is not significantly different from the thickness (1.3 in.) meeting the $1.5D_{50}$ criterion. These results confirm present guidance requiring a minimum thickness of $1.5D_{50}$ or $1D_{100}$, whichever is greater.

27. The other issue related to thickness is what is the impact of blanket thickness greater than $1D_{100}$ or $1.5D_{50}$? Testing of increased blanket thickness can be difficult because a large amount of rock movement occurs without exposure of the underlying material. It is emphasized that if the total benefits of increased layer thickness are going to be realized, then a significant amount of rock movement will occur before failure occurs.

28. Previous tests from Maynord (1988) and Abt et al. (1988) show that increased layer thickness increases riprap stability. The reasons for this increased stability include the following:

- a. For a single layer thickness, the stones are resting on either a smooth filter cloth, a granular surface, or a soil surface. The stones are not readily able to transmit the imposed fluid

forces to the underlying material by interlocking with the underlying material. For multiple layer thickness, the stones that are subjected to the fluid forces are resting on stones of similar size and can transmit forces to the underlayers, which increases stability. This is why angle of repose tests conducted with a hinged side slope show large angles when the underlying material is similar to the surface material (Miller and Byrne 1965).

b. For nonuniform ripraps, the potential for size segregation resulting in locally weak spots through the entire thickness is reduced with multiple layers.

29. Gradations 5, 6, and 7 had D_{85}/D_{15} of 2.1 and thicknesses of $1.5D_{100}$, $1.0D_{100}$, and $2.0D_{100}$, respectively. Results of stability tests on a 1V:2H side slope are shown in Table 12. Gradations 5 and 6 results were inconclusive because of the large difference in stability coefficient between the stable and failure runs. (A smaller increment of discharge between tests should have been used.) Gradation 6 had the same thickness as gradations 2, 4, and 8; so the stability coefficient of 0.36 (average of 2, 4, and 8) was used for gradation 6. Gradation 7 had a stability coefficient of 0.27 and the ratio C_t of stability coefficients of gradations 7 and 6 is shown in Plate 16 as a function of N, the relative layer thickness.

30. Gradations 8 and 9 had $D_{85}/D_{15} = 5.2$ and thicknesses of $1D_{100}$ and $2D_{100}$, respectively. Stability results for a 1V:2H side slope are shown in Table 12. Gradation 8 had the same thickness as gradations 2 and 4 and a similar stability coefficient of 0.35. Gradation 9 had a stability coefficient of 0.19, and the ratio C_t of the stability coefficients is also shown in Plate 16.

31. Abt et al. (1988) data for thickness effects for D_{85}/D_{15} of 2.5 results in $C_t = 0.83$ for $N = 1.5$ and $C_t = 0.70$ for $N = 2.0$ as shown in Plate 16. Also shown in Plate 16 is an interpolated curve for $D_{85}/D_{15} = 1.7$, which is the gradation coefficient typical of Corps gradations found in ETL 1110-2-120 (Headquarters, US Army Corps of Engineers, 1971). Thickness results shown in Plate 16 are more conservative than those presented in Maynord (1988). This is likely an effect of the longer run time used in RTF.

Stability of Rounded Rock

32. In channel bendway 3, 1V:2H side slope ($K = 0.88$), and riprap thickness of $1D_{100}$, stability tests evaluated gradations 10 and 11, which were

composed of stream-rounded stone. The stone used is referred to locally as "washed gravel" and has shape characteristics similar to crushed stone but with rounded edges. The stone was not predominantly near-spherical particles and had a specific weight of 159 pcf. Gradations 2 (angular) and 10 (rounded) were identical except for the rock type. Gradation 3 (angular) and 11 (rounded) were of different size but had the same gradation uniformity and thickness ($1D_{100}$). Results comparing gradations 2 and 10 and 3 and 11 are shown in Table 13. Comparing failure conditions for gradations 2 to 10 and making the same comparison for gradations 3 and 11 gives the size increases for rounded rock over angular rock of 13 and 21 percent, respectively. These results can be compared to Abt et al. (1988), who found a 31 percent increase required for rounded riprap when tested on an overflow embankment. Olivier (1967) found a 15 percent increase required for rounded riprap when tested on an overflow embankment.

Effects of Riprap Packing

33. At least one Corps District has reported that they pack or tamp riprap after placement to increase stability. This packing is usually done with a heavy plate or a broad-tracked bulldozer. After completing stability tests of gradation 6 in bendway 1 on a 1V:3H side slope with normal placement, the riprap was remolded and packed or tamped and retested for stability. Results are shown in the following tabulation:

Placement	Failure Q cfs	V_{20} fps	d_{20} ft	C (Equation 8)
Normal	65	3.30	1.40	0.361
Packed	75	3.47	1.53	0.325

Based on this single test, the packing of the riprap would permit a 10 percent size reduction.

Effects of Filter Type

34. Limited tests from Abt et al. (1986) and Ahmed (1987) show an increase in stability of riprap placed on a granular filter compared to riprap placed on filter fabric. Stability tests were conducted in bendway 3 with a

granular filter placed beneath gradations 2 and 2A and on top of the existing filter fabric used in all other tests. The gradation of the 1-in.-thick-granular filter is shown in Plate 18, and stability results are given in Table 14. As with the packing tests, these filter effect results are based on only a small number of tests (two), but results indicate about a 10 percent reduction in stone size when a granular filter was used based on a stability coefficient of 0.32-0.33.

PART V: SUMMARY AND CONCLUSION

35. The basic equation for riprap stability in straight and curved channels is

$$\frac{D_r}{d} = C\left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{1/2} \frac{V}{\sqrt{Kgd}}\right]^{2.5} \tag{12}$$

Local depth and local depth-averaged velocity are used as the characteristic parameters. For side slope riprap, the characteristic depth and velocity are located 20 percent up the slope from the toe. Side slope variation is given by K in Plate 10. Characteristic particle size is D_{30}. An alternate characteristic size is given by Equation 9 and is considered an improvement over a single particle size.

36. The stability coefficient C in Equation 8 for straight channels is 0.30 for angular rock and thickness = $1D_{100}$. The stability coefficient C for the bends of the RTF was 0.36 for angular rock and thickness = $1D_{100}$. Variation of C with R/W for application to other bends is given in Plate 16.

37. The RTF was used to address several limitations of the velocity-based riprap design procedure presented in Maynord (1988) and Maynord, Ruff, and Abt (1989). Stability testing was conducted using a practical equilibrium concept in which the riprap was tested for up to 72 hours to determine stability. Lower test durations were found to have a significant impact on the discharge at which the riprap failed.

38. Riprap thickness should be a minimum of $1.5D_{50}$ or $1D_{100}$, whichever is greater. For thickness greater than the minimum, riprap size can be reduced. Substantial reductions in stone size can be used with highly nonuniform riprap placed to thickness greater than $1D_{100}$.

39. Two tests of rounded rock resulted in a stability coefficient C in Equation 8 of 13 and 21 percent greater than angular rock.

40. One test of packing or tamping the riprap after it was placed resulted in a decrease in the stability coefficient of 10 percent.

41. Two tests with a granular filter beneath the riprap revetment versus geotextile resulted in a decrease in the stability coefficient for the granular filter of 10 percent.

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Table 1

Riprap Characteristics

Gradation Number	Angular (A) or Rounded (R)	$\frac{D_{85}}{D_{15}}$	$\frac{\text{Thickness}}{D_{100}}$	γ_s pcf	D_{30} ft	Gradation Plate No.
1	A	1.9	1.25	171	0.097	2
2	A	2.1	1.00	167	0.067	3
2A	A	2.1	1.00	167	0.063	3
3	A	1.2	1.00	167	0.068	3
4	A	3.1	1.00	167	0.063	4
5	A	2.1	1.50	167	0.046	5
6	A	2.1	1.00	167	0.046	5
7	A	2.1	2.00	167	0.046	5
8	A	5.2	1.00	167	0.042	6
9	A	5.2	2.00	167	0.042	6
10	R	2.1	1.00	159	0.067	3
11	R	1.3	1.00	159	0.094	7

Table 2

Riprap Shape Characteristics

Gradation	Sample Size	Percent Greater than L/b 2.5	3.0	3.5
2	22	50	27	23
	52	35	25	12
4	26	31	19	12
	58	36	14	9

Table 3

Summary of Velocity Measurements and Stability Results, 1V:2H Side Slope

Test No.	Grada-tion	Bend	Q cfs	Pumps	Temper-ature °F	Time hr	Stable (S) or Failed (F)	Velocity Station*	Plate
					Angular Stone				
1R1	2	1	70	C1,V1	--	72	S	281(E)	A10
								306(E)	A15
1R2	2	1	70	C1,V2	--	72	S	--	--
1R3	2	1	70	C1,V1	--	72	S	--	--
2R1	2	1	75	C1,V2	--	72	F	281(E)	A11
								306(E)	A16
3R1	2	1	80	C1,V1	--	76	F	281(E)	A12
								306(E)	A17
3R2	2	1	80	C1,V1	--	72	F	--	--
4R1	2	1	85	C1,V1	--	72	F	281(E)	A13
								306(E)	A18
4R2	2	1	85	C1,V1	--	72	F	--	--
5R1	2	1	90	C1,V1	--	72	F	281(E)	A14
								306(E)	A19
11R1	2	3	50	C2	--	6.3	S	--	--
11R2	2	3	50	C2	--	21	S	--	--
11R3	2	3	50	C2	--	72	S	--	--
12R1	2	3	60	V1,V2	--	9	S	--	--
12R2	2	3	60	V1,V2	--	23	S	--	--
12R3	2	3	60	V1,V2	--	72	S	--	--
12R4	2	3	60	V1,V2	--	72	S	--	--
13R1	2	3	70	V1,V2	--	15	S	578(E)	A20

(Continued)

* (E) - Electromagnetic velocity meter
(P) - Pitot tube

Table 3 (Continued)

Test No.	Gradation	Bend	Q cfs	Pumps	Temperature °F	Time hr	Stable (S) or Failed (F)	Velocity Station	Plate
				Angular Stone (Continued)					
13R2	2	3	70	V1,V2	--	16	F	--	--
13R3	2	3	70	C2,V2	--	24.5	F	--	--
14R1	2	3	80	V1,V2	--	12	F	--	--
14R2	2	3	80	C2,V2	--	3.5	F	--	--
6R1	3	1	60	V1,V2	--	72	S	281(P)	A33
								306(P)	A36
8R1	3	1	65	V1,V2	--	72	S	281(P)	A34
								306(P)	A37
7R1	3	1	70	V1,V2	--	72	F	281(P)	A35
								306(P)	A38
20R1	3	3	40	V1,V2	--	5	S	--	--
21R1	3	3	50	C2	--	28	S	578(E)	A39
21R2	3	3	50	C2	--	72	S	--	--
22R1	3	3	60	V1,V2	--	22	S	578(E)	A40
22R2	3	3	60	V1,V2	--	21	S	--	--
22R3	3	3	60	V1,V2	--	72	F	--	--
23R1	3	3	70	V1,V2	--	19	F	578(E)	A41
23R2	3	3	70	V1,V2	--	16	F	--	--
24R1	3	3	80	V2,C2	--	4	F	--	--
28R1	4	3	50	C1	--	55	S	--	--
29R1	4	3	60	V1,V2	--	72	S	--	--
30R1	4	3	70	C1,V1	--	73	S	--	--
30R2	4	3	70	C1,V1	--	72	F	--	--
30R3	4	3	70	C1,V2	--	72	S	--	--
30R4	4	3	70	C1,V1	--	72	F	578(E)	A42
								602(E)	A46

(Continued)

Table 3 (Continued)

Test No.	Grada-tion	Bend	Q cfs	Pumps	Temper-ature °F	Time hr	Stable (S) or Failed (F)	Velocity Station	Plate
				Angular Stone (Continued)					
34R1	4	3	75	C1,V1	--	75	F	578(E)	A43
								602(E)	A47
31R1	4	3	80	C1,V1	--	73	S	--	--
31R2	4	3	80	C1,V1	--	73	S	578(E)	A44
31R3	4	3	80	C1,V1	--	68	F	--	--
32R1	4	3	90	C1,V1	--	35	F	578(E)	A45
								602(E)	A48
36R1	5	3	40	V2	--	72	S	578(E)	A61
								602(E)	A64
37R1	5	3	50	C1	--	72	F	578(E)	A62
								602(E)	A65
35R1	5	3	60	V1,V2	--	72	F	578(E)	A63
								602(E)	A66
38R1	6	3	30	V2	--	72	S	578(E)	A85
								602(E)	A86
39R1	6	3	40	V1	--	72	F	--	--
40R1	7	3	50	C1	--	72	S	--	--
41R1	7	3	60	V1,V2	82-88	72	F	--	--
142R1	7	3	65	V1,V2	--	72	F	578(E)	A87
								602(E)	A88
43R1	8	3	40	V2	54-64	72	S	578(P)	A107
								602(P)	A110
44R1	8	3	45	V2	50-71	72	S	578(P)	A108
								602(P)	A111
44R2	8	3	45	V2	59-68	72	F	--	--

(Continued)

Table 3 (Continued)

Test No.	Grada-tion	Bend	Q cfs	Pumps	Temper-ature °F	Time hr	Stable (S) or Failed (F)	Velocity Station	Plate
					Angular Stone (Continued)				
45R1	8	3	50	C1	56-71	29	F	578(P)	A109
								602(P)	A112
46R1	9	3	50	C1	52-70	72	S	578(P)	A113
								602(P)	A118
47R1	9	3	60	V1,V2	52-63	72	S	578(P)	A114
								602(P)	A119
48R1	9	3	70	V1,V2	60-66	72	S	578(P)	A115
								602(P)	A120
48R2	9	3	70	V1,V2	45-56	72	S	--	--
49R1	9	3	80	V1,C1	50-67	72	S	578(P)	A116
								602(P)	A121
49R2	9	3	80	V1,C1	42-51	72	S	--	--
50R1	9	3	90	V1,C1	50-56	72	F	578(P)	A117
								602(P)	A122
50R2	9	3	90	V1,C1	47-48	23	F	--	--
					Rounded Stone				
51R1	10	3	45	V2	77-85	52	F	578(P)	A124
								602(P)	A131
51R2	10	3	45	V2	70-78	75	F	--	--
52R2	10	3	40	V2	71-79	72	S	578(P)	A123
								602(P)	A130
53R1	10	3	50	C1	78-81	48	F	578(P)	A125
								602(P)	A132
54R1	11	3	50	C1	73-84	72	S	578(P)	A126
								602(P)	A133

(Continued)

Table 3 (Concluded)

Test No.	Grada- tion	Bend	Q cfs	Pumps	Temper- ature °F	Time hr	Stable (S) or Failed (F)	Velocity Station	Plate
				Rounded Stone (Continued)					
55R1	11	3	55	V1,V2	74-82	72	S	578(P)	A127
								602(P)	A134
56R1	11	3	60	V1,V2	77-83	72	F	578(P)	A128
								602(P)	A135
56R2	11	3	60	V1,V2	81-89	72	S	--	--
57R1	11	3	65	V1,V2	78-90	72	F	578(P)	A129
								602(P)	A136
				Granular Filter Layer Test					
58R1	2A	3	60	C1,V2 (51,9)	61-65	72	S	578(P)	A145
								602(P)	A150
58R2	2A	3	60	C1,V2 (51,9)	46-65	72	S	--	--
58R3	2A	3	60	C1,V2 (51,9)	47-54	72	S	--	--
59R1	2A	3	55	C1,V2 (51,5)	58-65	68	S	578(P)	A144
								602(P)	A149
60R1	2A	3	65	C1,V2 (51,14)	50-57	67	F	578(P)	A146
								602(P)	A151
60R2	2	3	65	C1,V2 (51,14)	49-58	72	S	--	--
61R1	2	3	70	C1,V2 (51,19)	48-57	72	S	578(P)	A147
								602(P)	A152
62R1	2	3	75	C1,V2 (51,24)	60-64	70	F	578(P)	A148
								602(P)	A153

(Sheet 5 of 5)

Table 4

Summary of Velocity Measurements and Stability Results

1V:3H Side Slope

Test No.	Grada- tion	Bend	Q cfs	Pumps	Temper- ature °F	Time hr	Stable (S) or Failed (F)	Velocity Station*	Plate
					Normal Placement				
1R1	6	1	40	V2	58-64	72	S	281(P)	A67
								306(P)	A76
2R1	6	1	45	V2	62-70	72	S	281(P)	A68
								306(P)	A77
3R1	6	1	50	C1	53-64	72	S	281(P)	A69
								306(P)	A78
4R1	6	1	55	V1,V2	51-59	72	S	281(P)	A70
								306(P)	A79
4R2	6	1	55	V1,V2	61-66	72	S	--	--
5R1	6	1	60	V1,V2	54-65	72	S	281(P)	A71
								306(P)	A80
5R2	6	1	60	V1,V2	68-71	72	S	--	--
6R1	6	1	65	V1,V2	51-60	72	F	281(P)	A72
								306(P)	A81
6R2	6	1	65	V1,V2	65-74	72	F	--	--
6R3	6	1	65	V1,V2	54-67	72	S	--	--
7R1	6	1	70	V1,V2	64-71	72	F	281(P)	A73
								306(P)	A82
8R1	6	1	75	V1,V2	62-72	72	F	281(P)	A74
								306(P)	A83

(Continued)

* (E) - Electromagnetic velocity meter
(P) - Pitot tube

Table 4 (Concluded)

Test No.	Gradation	Bend	Q cfs	Pumps	Temperature °F	Time hr	Stable (S) or Failed (F)	Velocity Station	Plate
					Riprap Packed				
9R1	6	1	70	V1,V2	56-74	72	S	--	--
10R1	6	1	75	C1,V1	56-70	72	F	--	--
10R2	6	1	75	C1,V1	60-66	72	F	--	--
11R1	6	1	80	C1,V1	62,72	72	F	281(P)	A75
								306(P)	A84
					Normal Placement				
12R1	8	1	45	V2	77-85	52	S	281(P)	A89
								306(P)	A98
13R1	8	1	50	C1	78-81	48	S	281(P)	A90
								306(P)	A99
14R1	8	1	65	V1,V2	78-90	72	S	281(P)	A91
								306(P)	A100
15R1	8	1	70	V1,V2	86-94	72	S	281(P)	A92
								306(P)	A101
16R1	8	1	75	C1,V1	87-95	72	S	281(P)	A93
								306(P)	A102
17R1	8	1	80	C1,V1	78-93	69	S	281(P)	A94
								306(P)	A103
18R1	8	1	85	C1,V1	86-94	72	S	281(P)	A95
								306(P)	A104
18R2	8	1	85	C1,V1	80-89	72	S	--	--
19R1	8	1	90	C1,V1	86-93	72	S	281(P)	A96
								306(P)	A105
19R2	8	1	90	C1,V1	84-92	72	F	--	--
20R1	8	1	95	C1,V1	86-94	72	F	281(P)	A97
								306(P)	A106
20R2	8	1	95	C1,V1	86-92	72	F	--	--

Table 5

Summary of Velocity Measurements and Stability Results

1V:1.5H Side Slope

Test No.	Gradation	Bend	Q cfs	Pumps	Temperature °F	Time hr	Stable (S) or Failed (F)	Velocity Station*	Plate
1R1	2	1	40	V2(40)	77-90	72	S	281(P) 306(P)	A21 A27
2R1	2	1	45	V2(45)	84-92	73	S	281(P) 306(P)	A22 A28
3R1	2	1	50	C1(50)	84-94	72	S	--	--
4R1	2	1	55	V1,V2 (30,25)	84-92	74	S	--	--
4R2	2	1	55	V1,V2 (30,25)	83-91	72	S	281(P) 306(P)	A23 A29
5R1	2	1	60	V1,V2 (30,30)	86-94	72	F	--	--
5R2	2	1	60	V1,V2 (30,30)	--	--	S	281(P) 306(P)	A24 A30
6R1	2	1	65	V1,V2 (30,35)	79-85	72	S	281(P) 306(P)	A25 A31
7R1	2	1	70	C1,V2 (51,19)	82-89	56	F	281(P) 306(P)	A26 A32
8R1	4	1	50	C1(50)	56-68	72	S	281(P) 306(P)	A49 A55
9R1	4	1	55	C1,V2 (51,4)	58-66	72	S	281(P) 306(P)	A50 A56
10R1	4	1	60	C1,V2 (51,9)	58-68	72	S	281(P) 306(P)	A51 A57

(Continued)

* (E) - Electromagnetic velocity meter
(P) - Pitot tube

Table 5 (Concluded)

Test No.	Grada-tion	Bend	Q cfs	Pumps	Temper-ature °F	Time hr	Stable (S) or Failed (F)	Velocity Station	Plate
10R2	4	1	60	C1,V2 (51,9)	56-61	70	S	-- --	-- --
10R3	4	1	60	C1,V2 (51,9)	61-65	72	S	--	--
11R1	4	1	65	C1,V2 (51,14)	62-73	72	F	281(P) 306(P)	A52 A58
11R2	4	1	65	C1,V2 (51,14)	56-65	72	S	--	--
11R31	4	1	65	C1,V2 (51,14)	51-57	67	S	--	--
12R1	4	1	70	C1,V2 (51,19)	57-66	72	S	281(P) 306(P)	A53 A59
13R1	4	1	75	C1,V2 (51,24)	62-67	46	F	281(P) 306(P)	A54 A60

Table 6

Summary of Velocity Measurements and Stability Results, Channel Bottom

Test No.	Q cfs	Pumps	Temperature °F	Time t hr	Stable (S) or Failed (F)	V fps	d ft	C (Equation 8)	$\frac{Vt/d}{10^5}$
1R1	60	V1,V2	54-63	72	S	2.89	1.62	0.53	4.6
2R1	70	V1,V2	60-66	72	S	3.05	1.75	0.48	4.5
3R1	80	C1,V1	50-67	72	S	3.22	1.92	0.43	4.3
4R1	90	C1,V1	50-56	72	S	3.37	2.03	0.39	4.3
5R1	100	C1,V1	41-44	72	S	3.39	2.17	0.39	4.0
6R1	110	C1,V1,V2	46-56	72	S	3.56	2.26	0.34	4.1
7R1	120	C1,V1,V2	50-52	52	F	3.69	2.39	0.32	4.0

Note: Velocities and depths were measured at the channel center line at sta 1+63 with a pitot tube.

Table 7

Straight Channel, 1V:2H Side Slope Tests

CSU Phase IV, D_{30} = 0.036 ft, γ_s = 167 pcf

Thickness = $1D_{100}$, D_{85}/D_{15} = 2.0

Run No.	Q cfs	V_{20} fps	d_{20} ft	Side Slope Stable (S) or Failed (F)
1	15	1.77	0.91	S
2		1.94	0.79	S
3		1.95	0.78	S
5		2.40	0.76	S
15	20	2.84	0.89	S
16		2.83	0.85	F
17		2.83	0.86	S
10	30	3.02	1.27	S
11		3.21	1.24	S
12		2.98	1.31	F
13		3.18	1.19	S
14		3.28	1.16	F
23		3.88	1.14	F
18	35	3.34	1.39	F
19		3.51	1.30	F
6	40	3.70	1.34	F
7		3.76	1.38	F
8		3.59	1.40	F
9		3.20	1.59	S
22		2.69	1.79	S

Table 8

Straight Channel, 1V:2H Side Slope Tests

CSU Phase IV, D_{30} = 0.073 ft, γ_s = 167 pcf

Thickness = $1D_{100}$, D_{85}/D_{15} = 2.3

Run No.	Q cfs	V_{20} fps	d_{20} ft	Side Slope Stable (S) or Failed (F)
36	15	3.06	0.66	S
37		3.62	0.61	S
38		3.54	0.57	S
39		3.52	0.59	S
40	20	3.69	0.70	S
41		3.49	0.72	S
42	30	3.93	0.94	F
43		3.64	1.04	S
44		3.94	0.94	S
45	40	3.80	1.27	S
46		3.81	1.30	S
47	50	4.28	1.50	S
48		4.54	1.37	S
49		4.60	1.37	F
50		4.70	1.35	F

Table 9

Riprap Failures in Channel Bends

RTF, 1V:2H Side Slopes, Thickness = $1D_{100}$

Gradation	Bend	Q cfs	V_{20} fps	V_{20} Source*	d_{20} ft	Stable (S) or Failed (F)	C (Equation 8)
2	1	70	3.39	M	1.53	S	0.44
	1	75	3.64	M	1.55	S	0.37
	1	80	3.67	M	1.60	F	0.36
	1	85	3.72	M	1.65	F	0.35
	3	60	3.46	RC	1.30	S	0.40
	3	70	3.69	M	1.43	F	0.35
4	3	60	3.46	RC	1.30	S	0.38
	3	70	3.65	M	1.44	F	0.34
6	3	30	2.66	M	0.82	S	0.47
	3	40	2.98	M	0.97	F	0.37
8	3	40	2.82	M	0.97	S	0.39
	3	45	2.97	M	1.05	S	0.35
	3	45	2.97	M	1.05	F	0.35
	3	50	3.23	M	1.11	F	0.29

Note: Velocity and depth from sta 3+06 and 5+78 in bends 1 and 3, respectively.

* M = Velocity from measurements taken during test.

RC = Velocity from rating curve based on measurements taken during other tests.

Table 10

Riprap Failures in Channel Bends, Bendway 1

RTF, 1V:3H Side Slopes, Thickness = $1D_{100}$

Gradation	Q cfs	V_{20} fps*	d_{20} ft	Stable (S) or Failed (F)	C (Equation 8)
6	40	2.52	1.07	S	0.66
	45	2.70	1.17	S	0.57
	50	2.96	1.24	S	0.46
	55	3.11	1.29	S	0.41
	60	3.25	1.35	S	0.37
	65	3.30	1.40	F	0.36
	65	3.30	1.40	S	0.36
	70	3.36	1.46	F	0.35
	75	3.47	1.53	F	0.33
8	65	3.30	1.32	S	0.32
	70	3.41	1.38	S	0.30
	75	3.51	1.45	S	0.28
	80	3.59	1.48	S**	0.27
	85	3.66	1.54	S**	0.26
	90	3.70	1.59	S**	0.26
	90	3.70	1.59	F	0.26
	95	3.75	1.64	F	0.25

* Velocity measurements were taken during the test. Velocity and depth from sta 3+06.

** Observer reported significant rock movement.

Table 11

Riprap Failures in Channel Bends, Bendway 1

RTF, 1V:1.5H Side Slopes, Thickness = $1D_{100}$

Gradation	Q cfs	V_{20} fps*	d_{20} ft	Stable (S) or Failed (F)	C (Equation 8)
2	40	2.50	1.01	S	0.66
	45	2.65	1.09	S	0.58
	55	3.17	1.22	S	0.38
	60	3.28	1.26	F	0.35
	65	3.37	1.30	F	0.33
	70	3.50	1.37	F	0.31
4	50	3.09	1.16	S	0.38
	55	3.02	1.20	S	0.40
	60	3.28	1.33	S	0.34
	65	3.35	1.29	F	0.32
	65	3.35	1.29	S	0.32
	70	3.48	1.35	S	0.29
	75	3.49	1.44	F	0.29

* Velocity measurements taken during test.

Table 12

Thickness Effects Tests

Gradation	Q cfs	D_{30} ft	Thickness D_{100}	Result	V_{20} fps	d_{20} ft	C (Equation 8)
5	40	0.046	1.5	S	2.98	0.97	0.37
	50	0.046	1.5	F	3.38	1.18	0.28
6	30	0.046	1.0	S	2.70	0.90	0.47
	40	0.046	1.0	F	2.98	0.97	0.37
7	50	0.046	2.0	S	3.38	0.90	0.28
	60	0.046	2.0	F	3.49	1.28	0.27
8	40	0.042	1.0	S	2.82	0.97	0.39
	45	0.042	1.0	F	2.97	1.05	0.35
9	80	0.042	2.0	S	3.87	1.26	0.19
	90	0.042	2.0	F	4.00	1.29	0.19

Table 13

Stream-Rounded Rock Stability

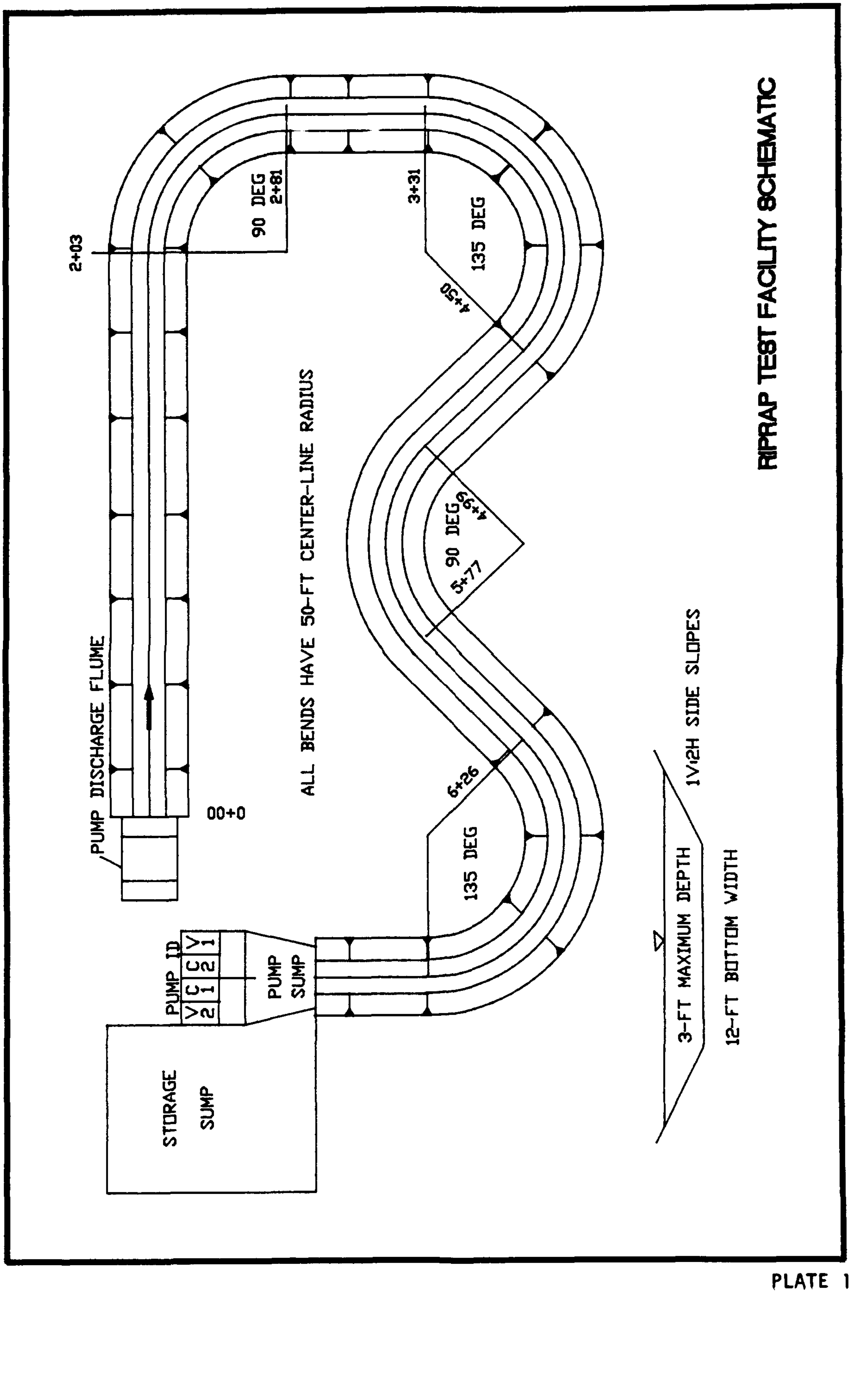
Gradation	Q cfs	D_{30} ft	Specific Weight	Stable (S) or Failed (F)	V_{20} fps	d_{20} ft	C (Equation 8)
2	60	0.067	167	S	3.46	1.30	0.40
	70	0.067	167	F	3.69	1.43	0.35
10	40	0.067	159	S	3.11	0.94	0.44
	45	0.067	159	F	3.26	1.03	0.40
3	50	0.068	167	S	3.21	1.23	0.48
	60	0.068	167	F	3.53	1.34	0.39
11	55	0.094	159	S	3.41	1.17	0.51
	60	0.094	159	F	3.54	1.25	0.47

Table 14

Stability with Filter Rock

Specific Weight 167 pcf

Gradation	Q cfs	D_{30} ft	Stable (S) or Failed (F)	V_{20} fps	d_{20} ft	C (Equation 8)
2A	60	0.063	S	3.48	1.17	0.36
	65	0.063	F	3.64	1.22	0.33
2	70	0.067	S	3.64	1.32	0.35
	75	0.067	F	3.78	1.36	0.32


RIPRAP TEST FACILITY SCHEMATIC
ALL BENDS HAVE 50-FT CENTER-LINE RADIUS
PUMP DISCHARGE FLUME
00+0
2+03
90 DEG
2+81
3+31
135 DEG
4+50
90 DEG
4+99
5+77
6+26
135 DEG
PUMP ID
V 2
C 1
C 2
V 1
PUMP SUMP
STORAGE SUMP
1V:2H SIDE SLOPES
3-FT MAXIMUM DEPTH
12-FT BOTTOM WIDTH

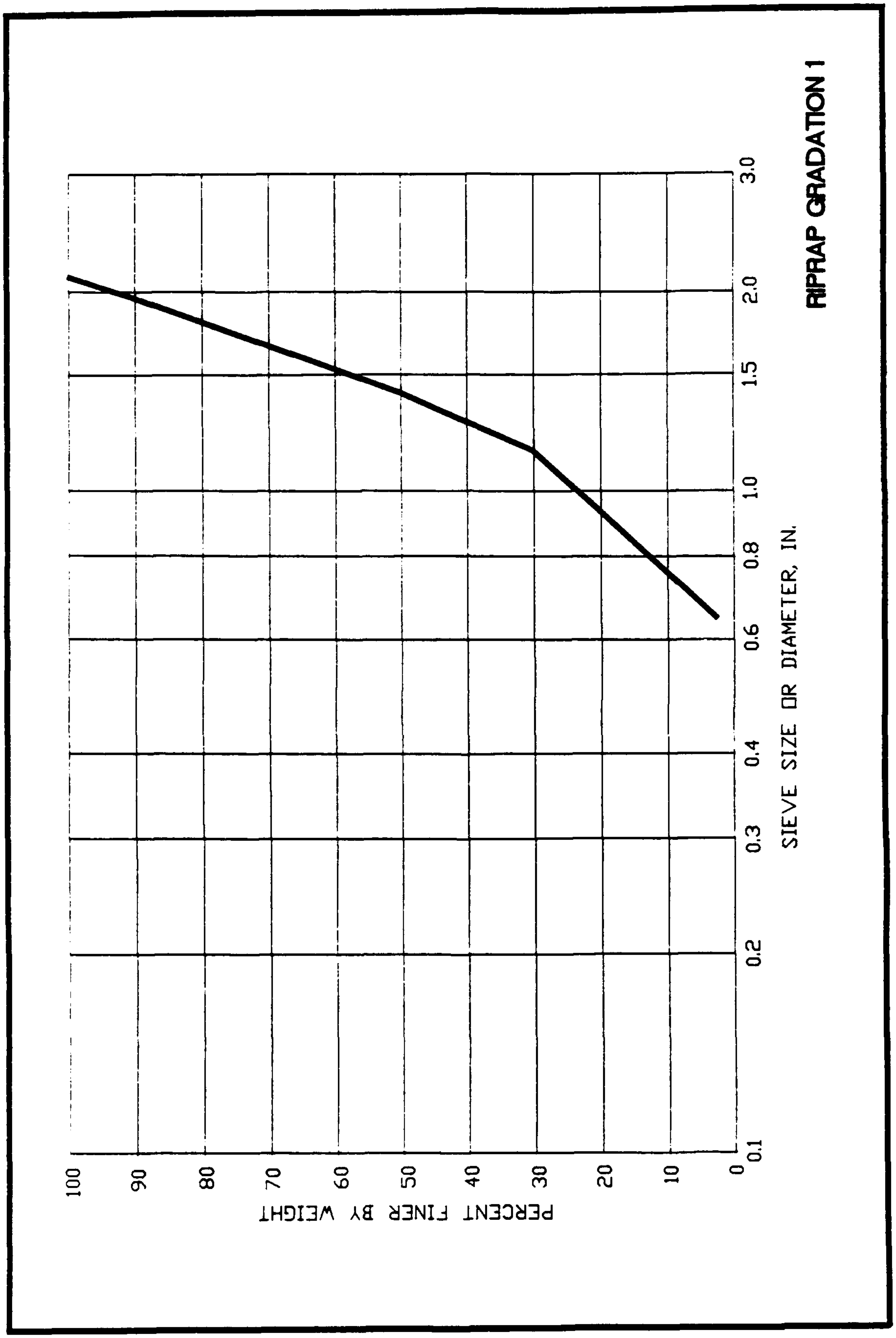
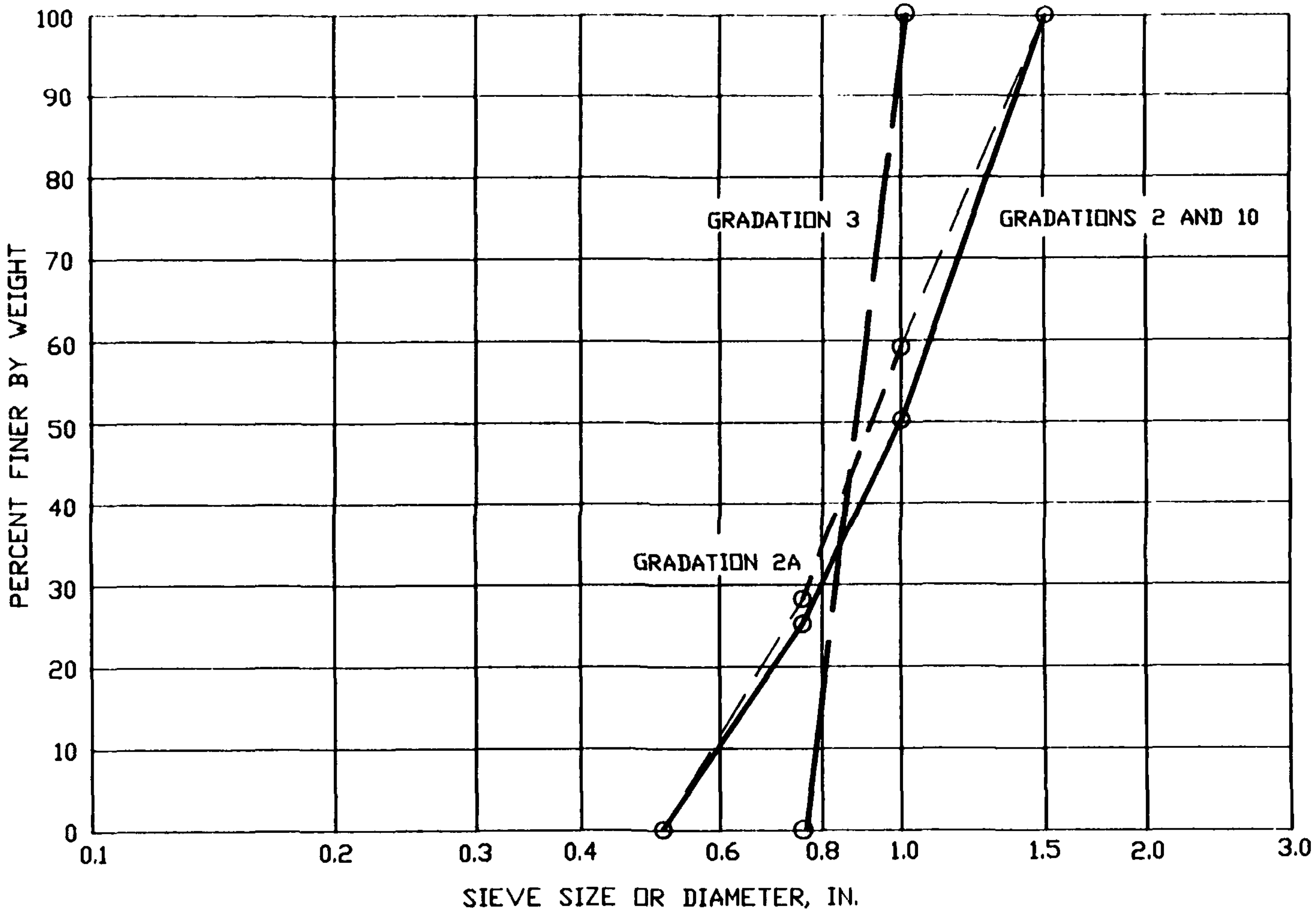
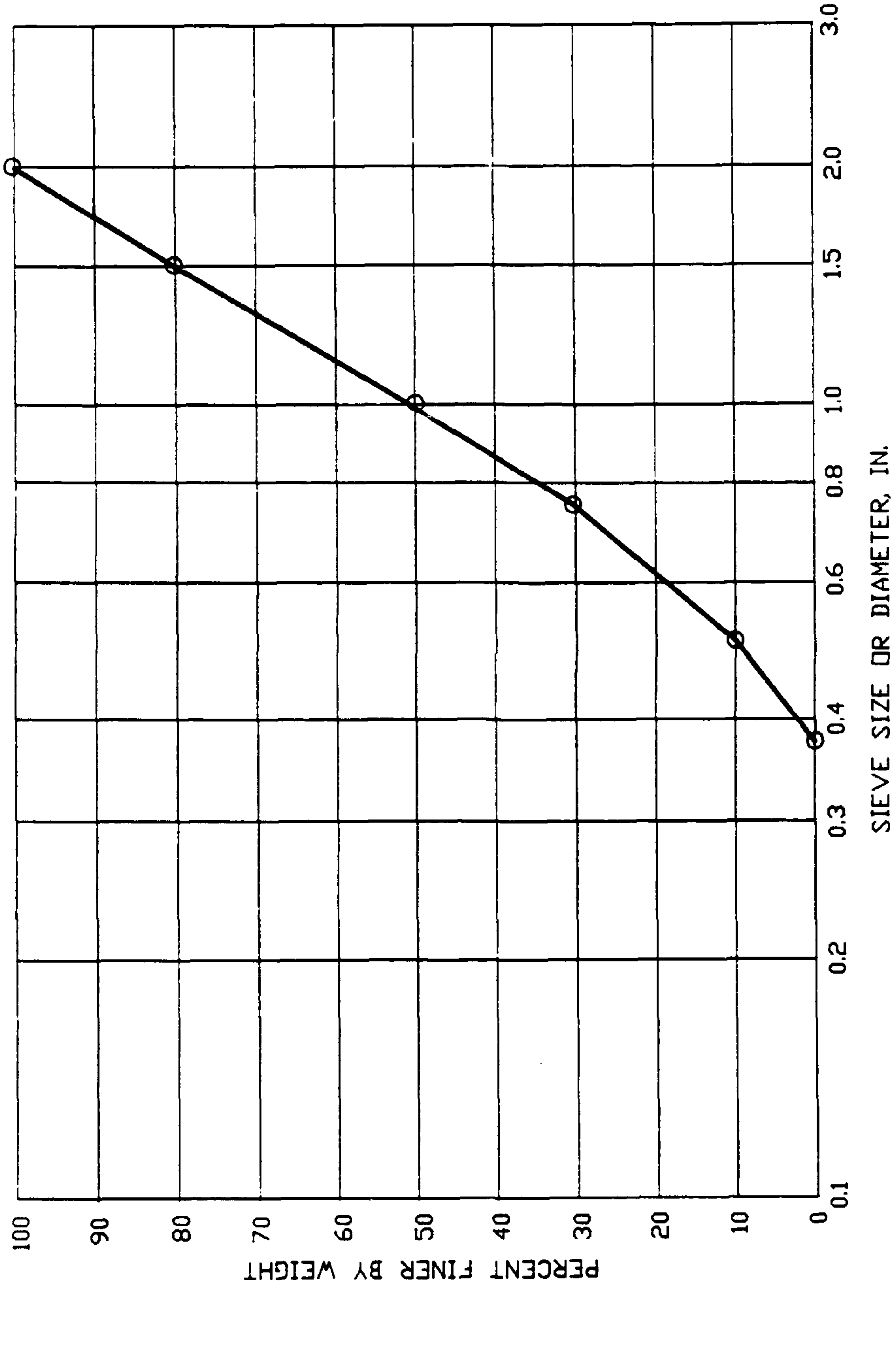

RIPRAP GRADATION 1
PERCENT FINER BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
SIEVE SIZE OR DIAMETER, IN.
0.1
0.2
0.3
0.4
0.6
0.8
1.0
1.5
2.0
3.0

PLATE 2



RIPRAP GRADATIONS 2, 2A, 3, AND 10



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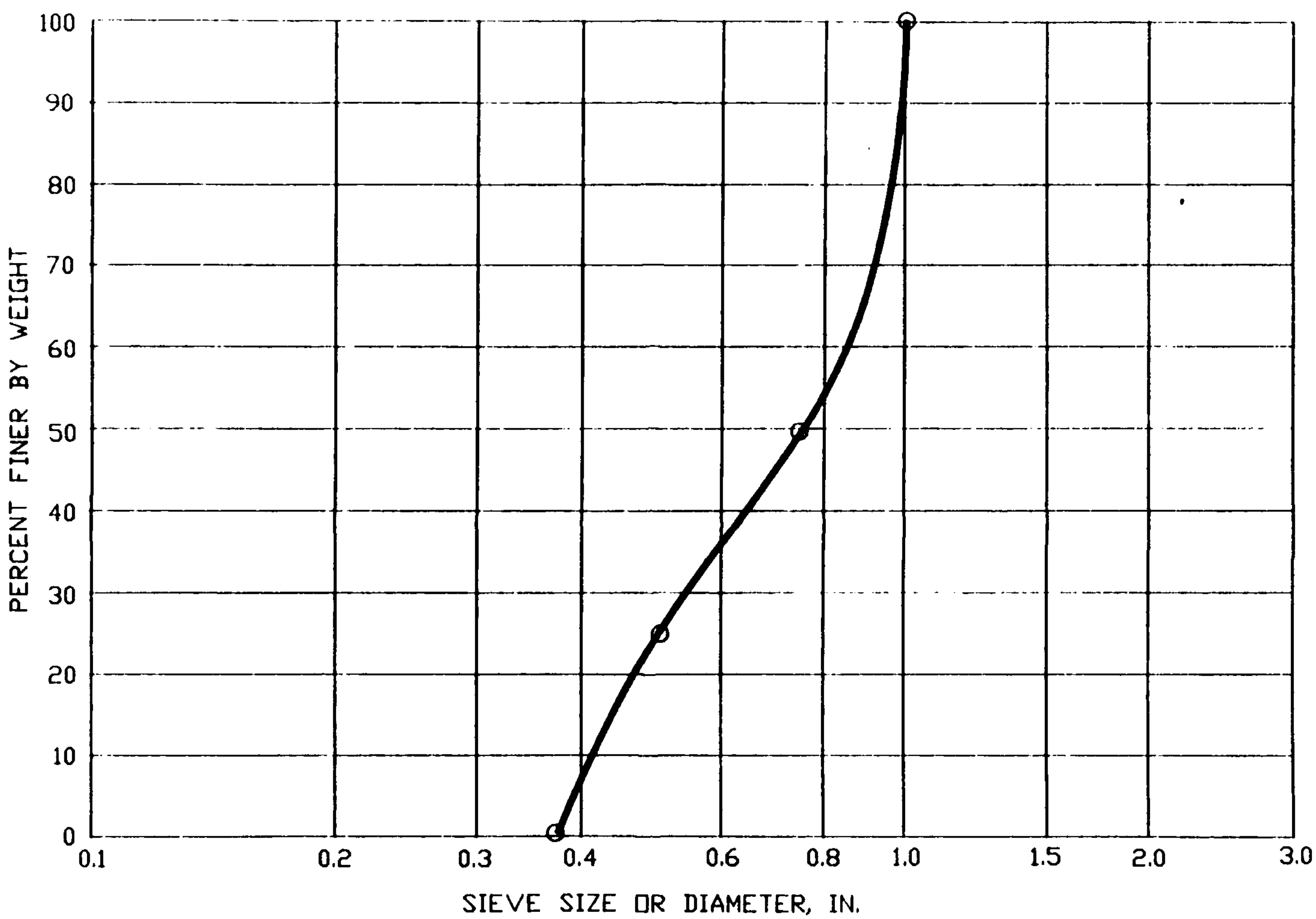
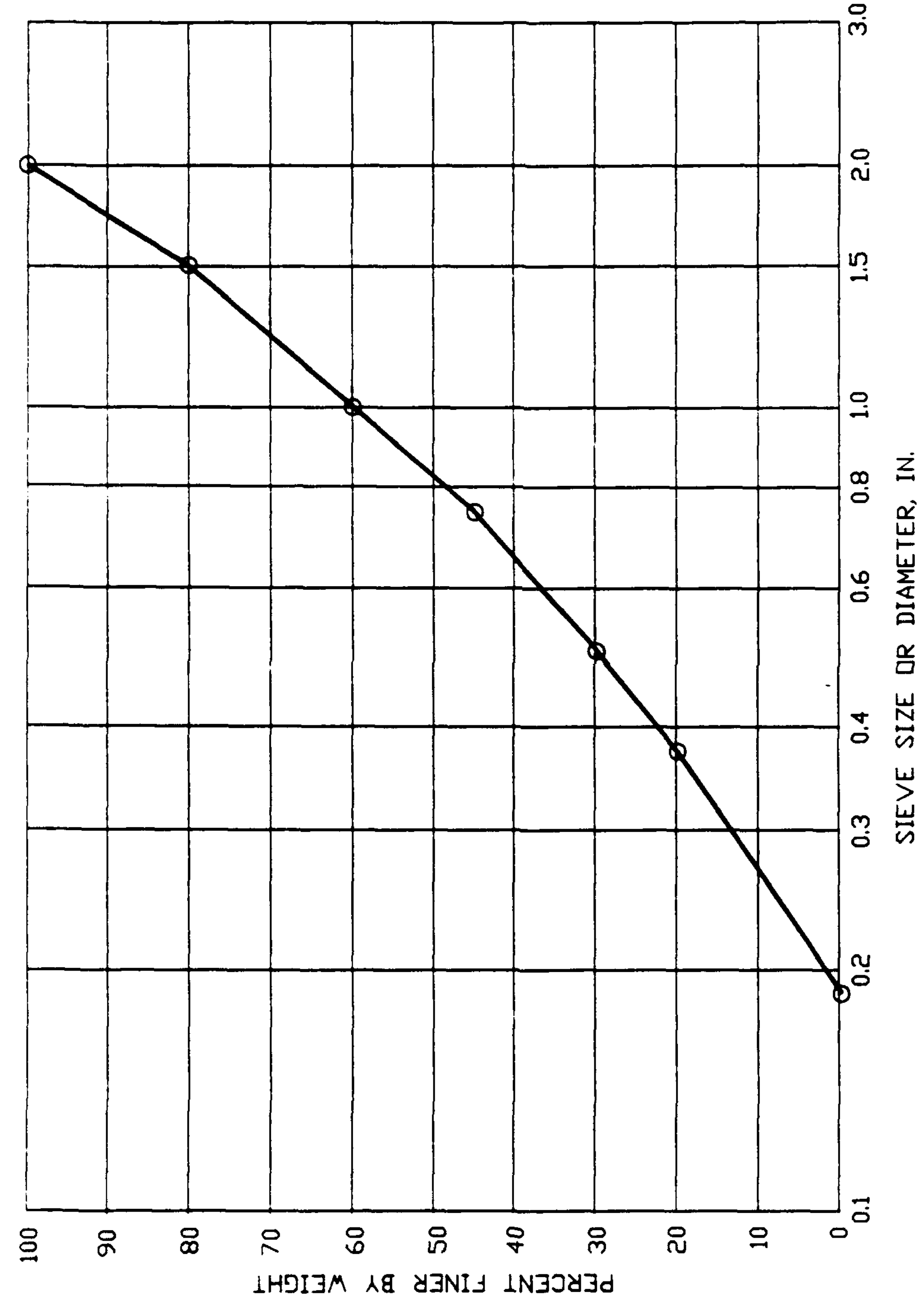
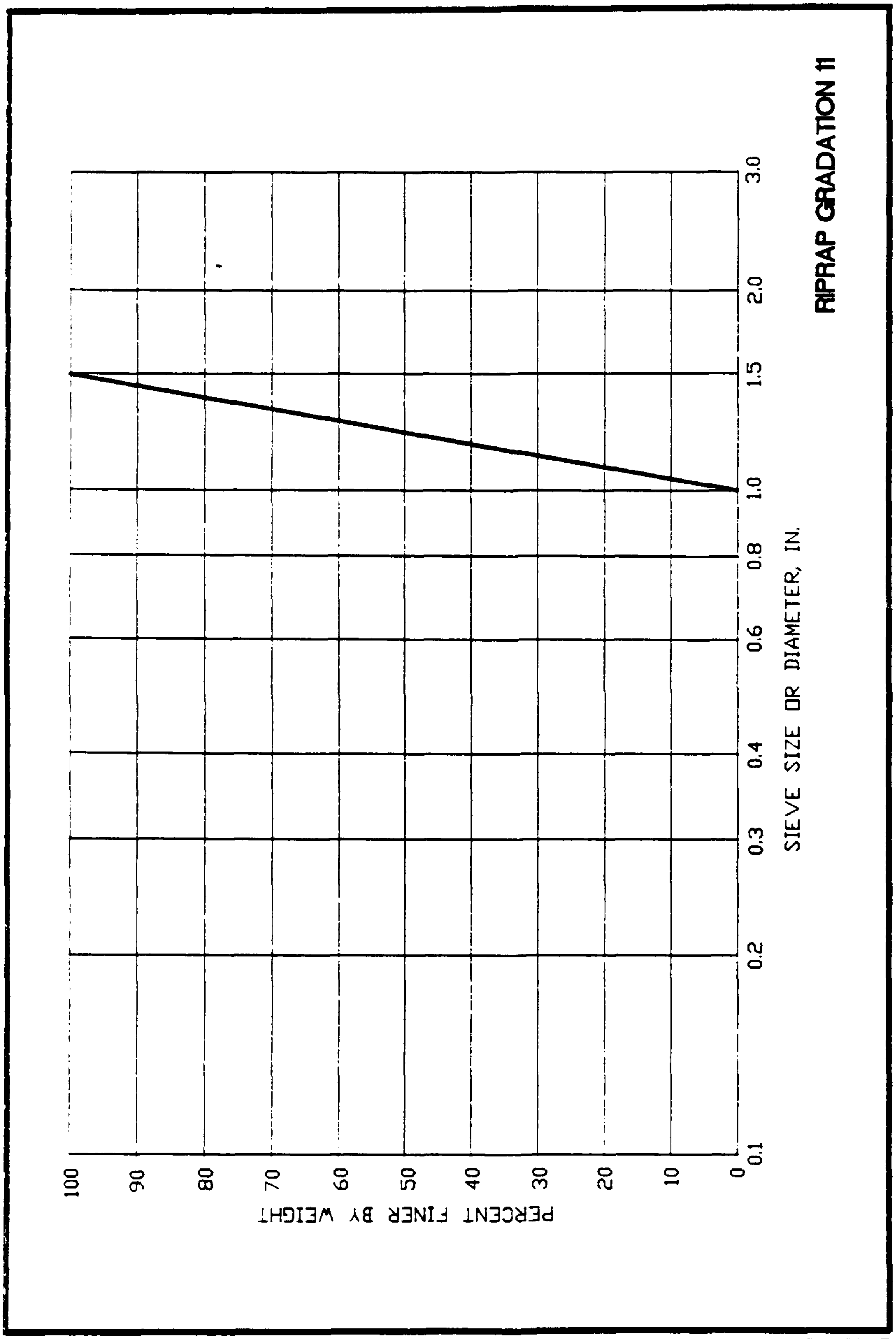


RIPRAP GRADATIONS 5,6, AND 7



RIPRAP GRADATIONS 8 AND 9

PLATE 6


RIPRAP GRADATION 11
PERCENT FINER BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
SIEVE SIZE OR DIAMETER, IN.
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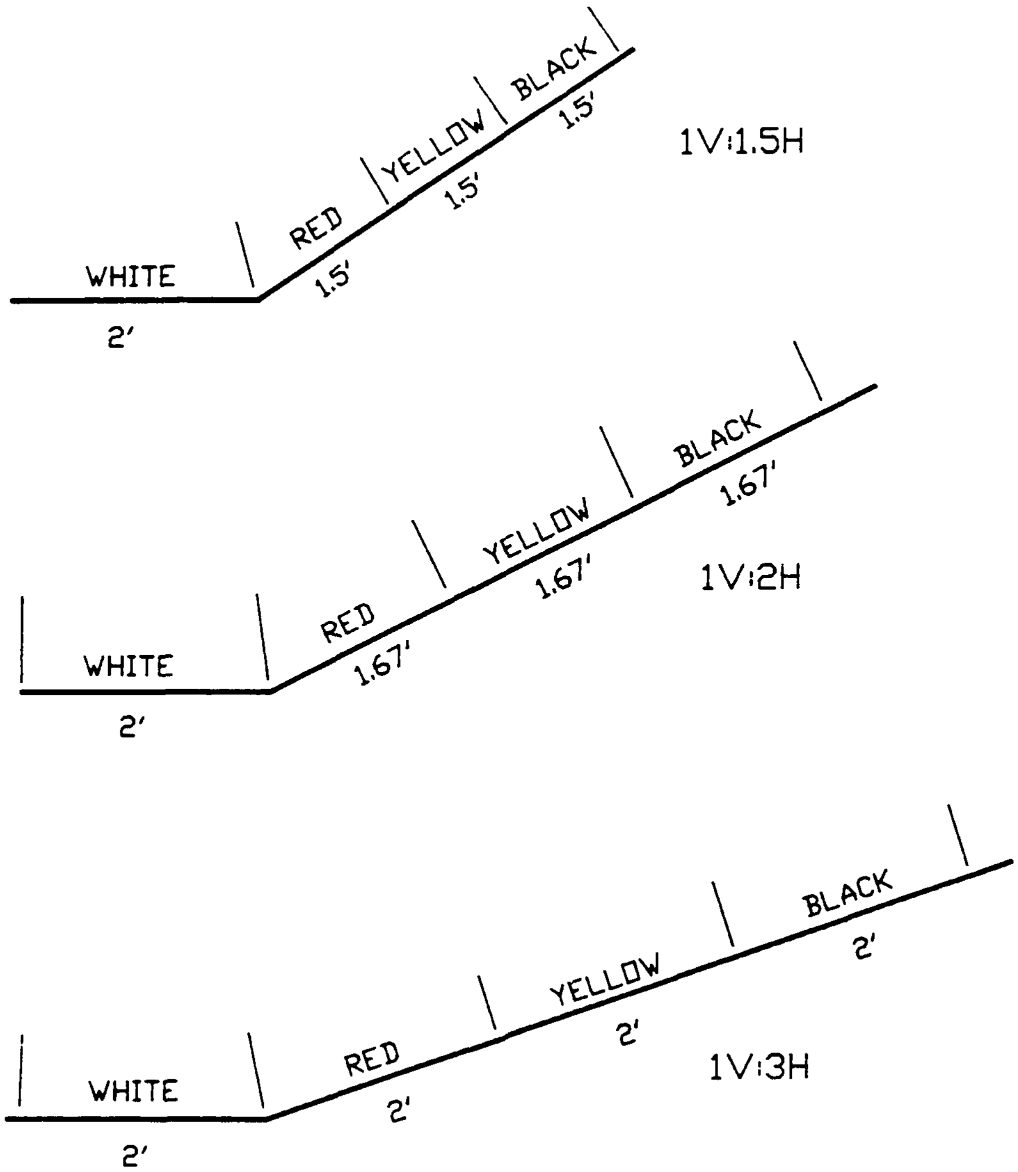
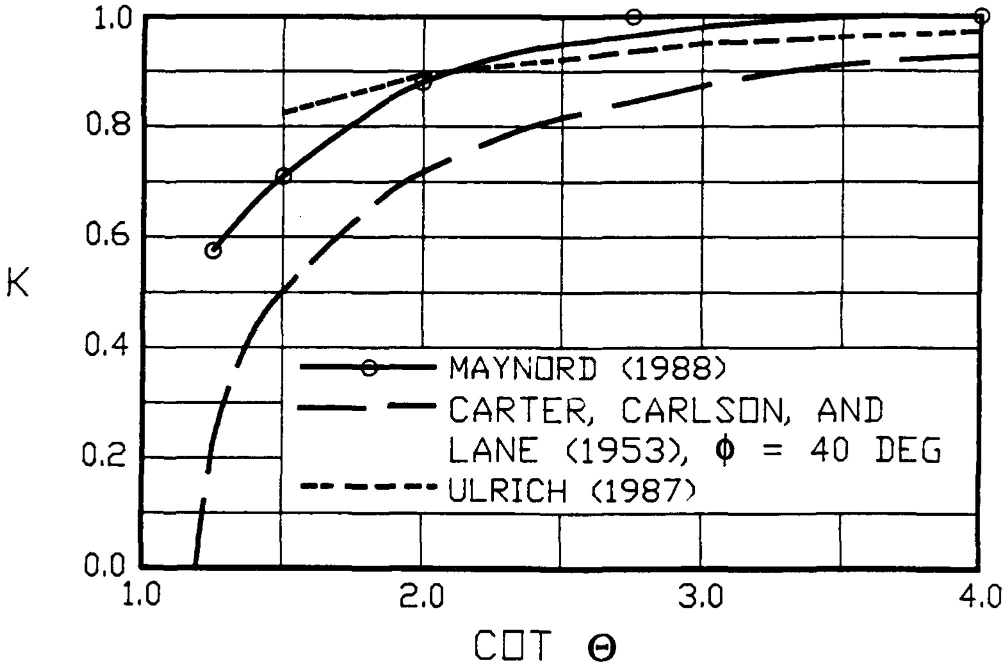
0.2
0.3
0.4
0.6
0.8
1.0
1.5
2.0
3.0

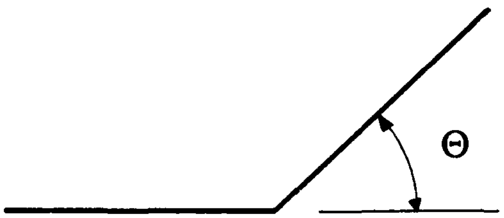


PAINTED SIDE SLOPE CONFIGURATION

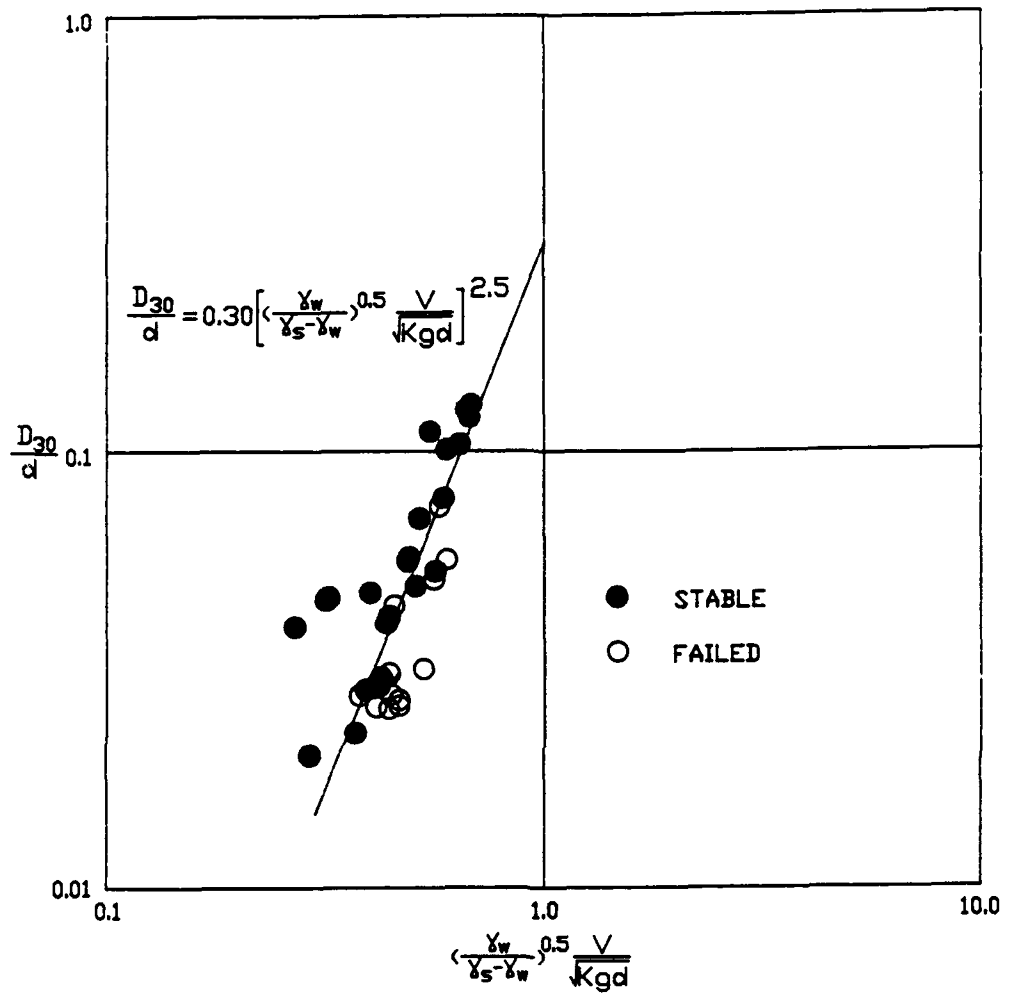


K = SIDE SLOPE CORRECTION COEFFICIENT

φ = ANGLE OF REPOSE



CORRECTION FOR SIDE SLOPE ANGLE



VELOCITY AND DEPTH MEASURED 20%

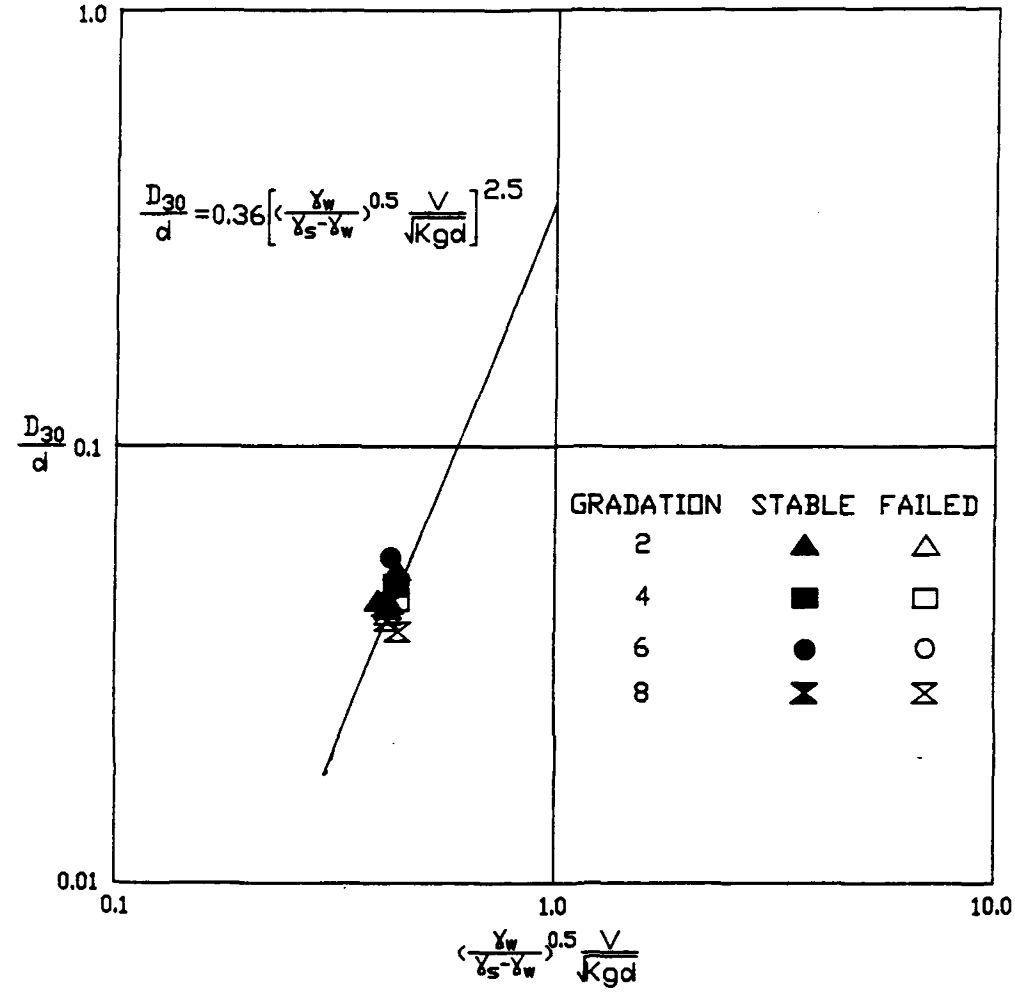
UP SLOPE FROM TOE

THICKNESS $1D_{100}$

RIPRAP STABILITY

STRAIGHT CHANNEL

1V:2H SIDE SLOPE



VELOCITY AND DEPTH MEASURED 20%

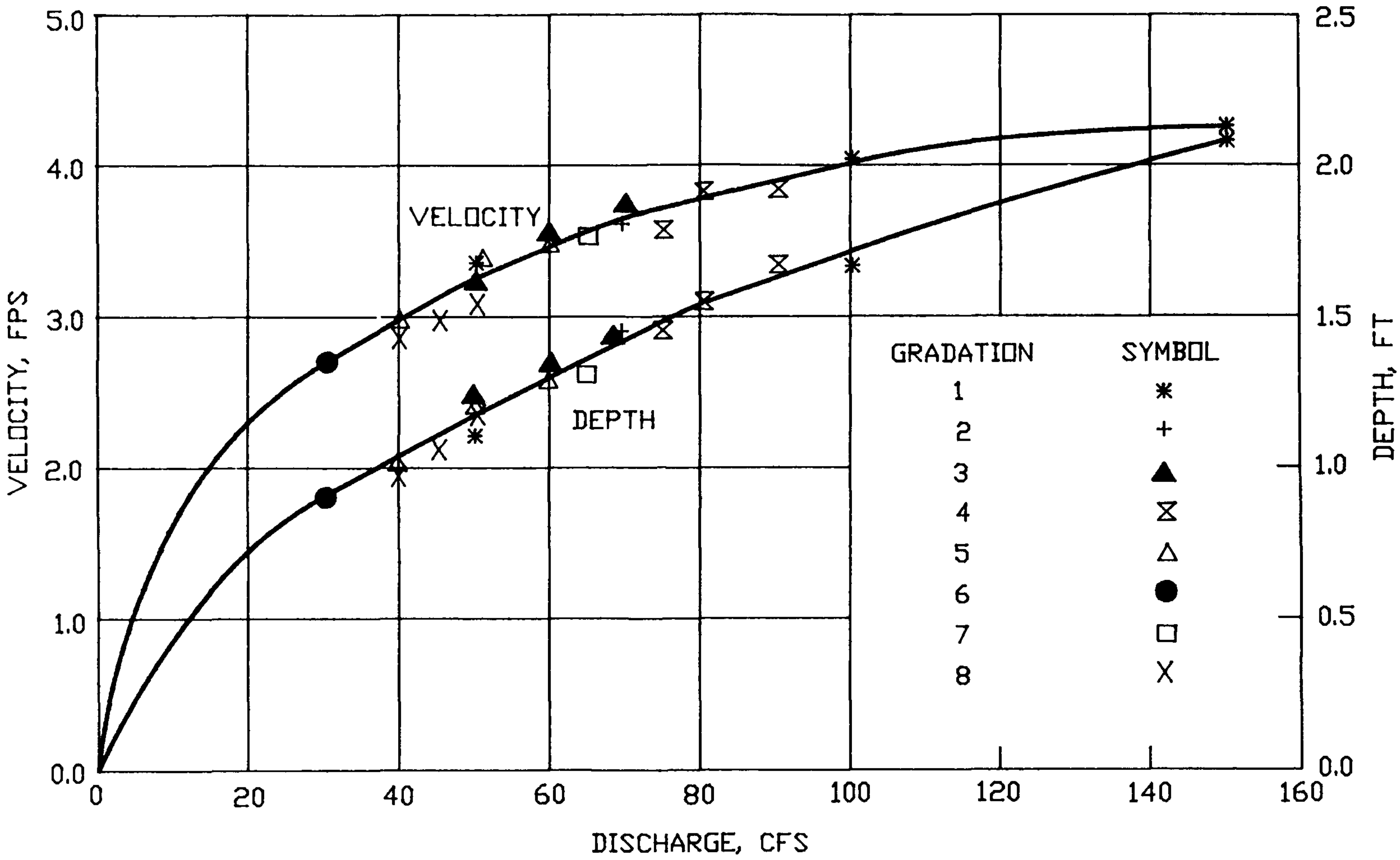
UP SLOPE FROM TOE

THICKNESS $1D_{100}$

RIPRAP STABILITY

CURVED CHANNEL

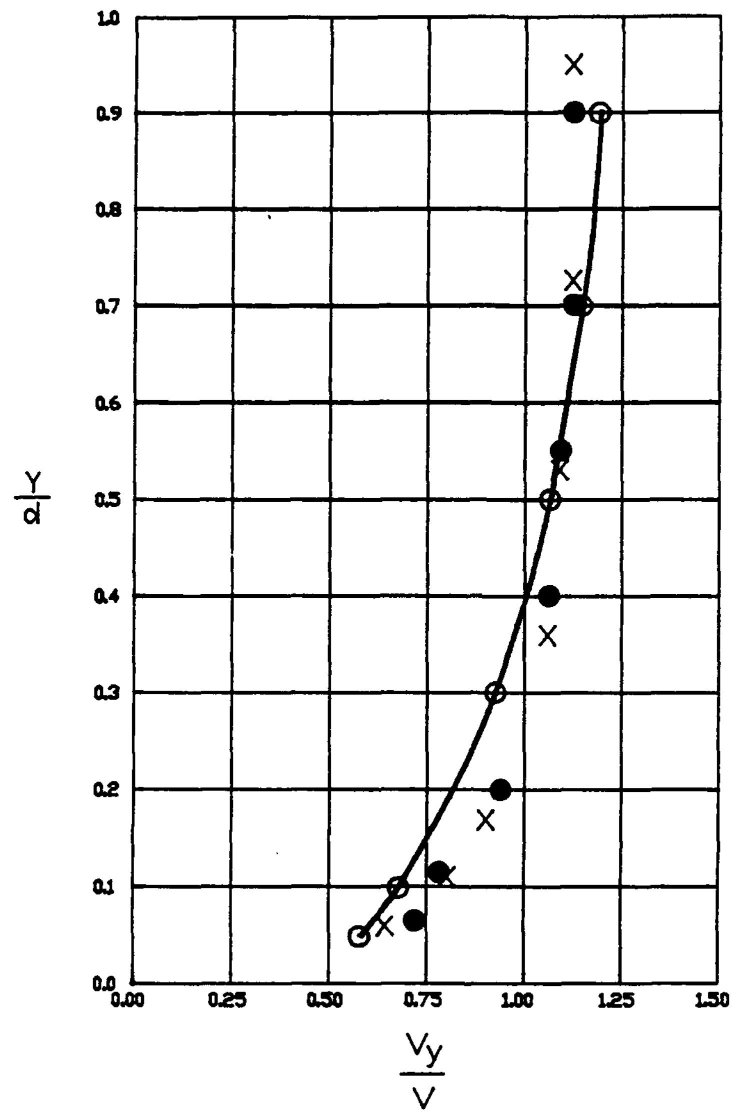
1V:2H SIDE SLOPE



VELOCITY AND DEPTH 20% UP SLOPE FROM TOE

VELOCITY AND DEPTH VERSUS DISCHARGE

STA. 5+78, 1V:2H SIDE SLOPE



O AVERAGE OF 21 VELOCITY PROFILES
FROM STRAIGHT FLUME, BOTTOM RIPRAP
d/D_{90} FROM 5 TO 13
AVERAGE d/D_{90} = 8.3

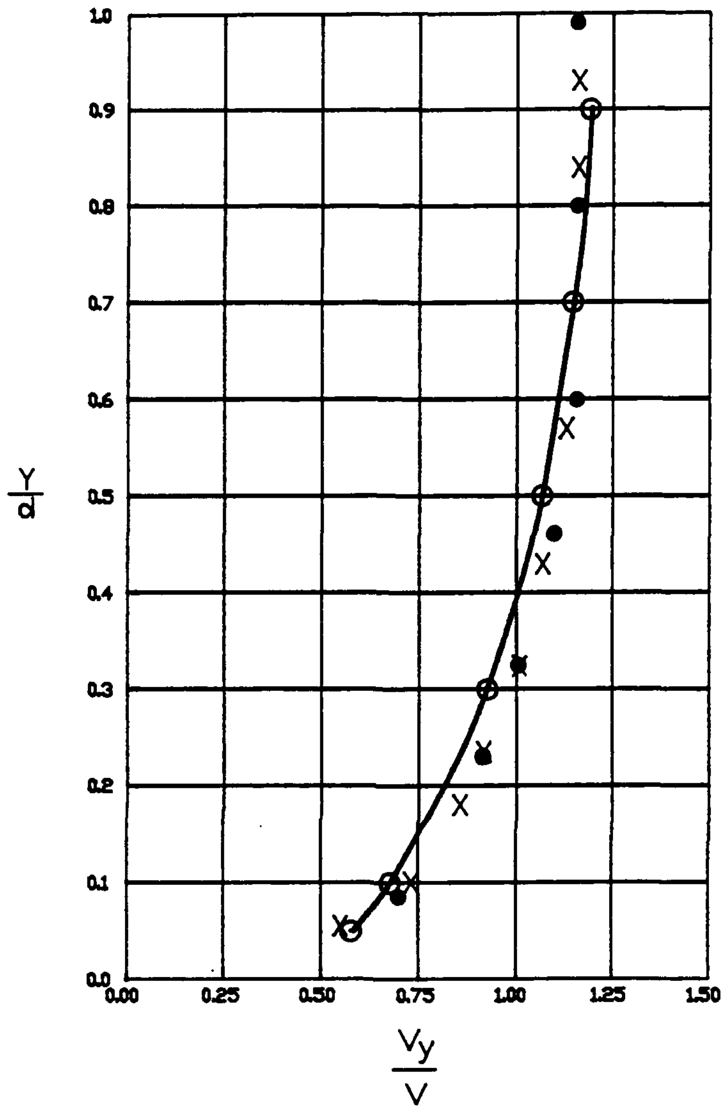
——— BEST FIT LINE OF STRAIGHT FLUME DATA

DATA FROM RIPRAP TEST FACILITY, BENDWAY 1,
GRADATION 6, NORMAL TO SIDE SLOPE,
20% UP SLOPE FROM TOE

X 60 CFS
● 65 CFS

VELOCITY PROFILE

STRAIGHT FLUME, BOTTOM RIPRAP
VERSUS CURVED CHANNEL, SIDE
SLOPE RIPRAP, STA 2+81, 1V:3H



O AVERAGE OF 21 VELOCITY PROFILES FROM STRAIGHT FLUME, BOTTOM RIPRAP d/D_{90} FROM 5 TO 13 AVERAGE d/D_{90} = 8.3

——— BEST FIT LINE OF STRAIGHT FLUME DATA

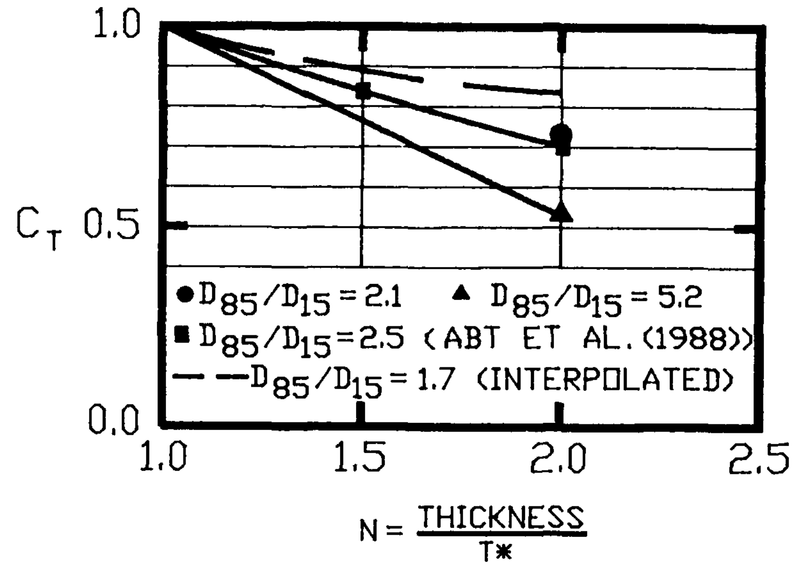
DATA FROM RIPRAP TEST FACILITY, BENDWAY 1, GRADATION 6, NORMAL TO SIDE SLOPE, 20% UP SLOPE FROM TOE

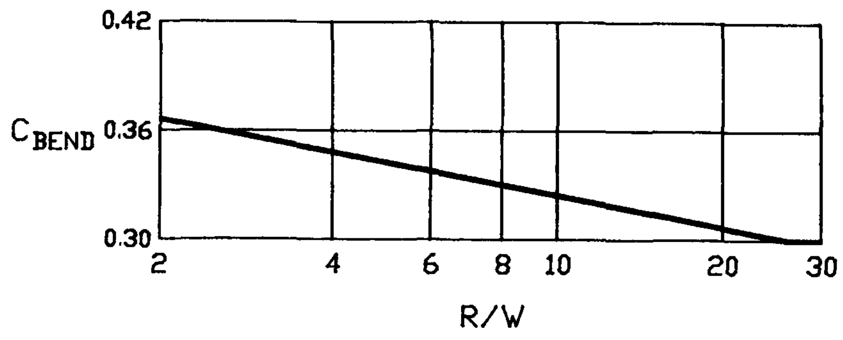
X 60 CFS

● 65 CFS

VELOCITY PROFILE

STRAIGHT FLUME, BOTTOM RIPRAP VERSUS CURVED CHANNEL, SIDE SLOPE RIPRAP, STA 3+06 , 1V:3H



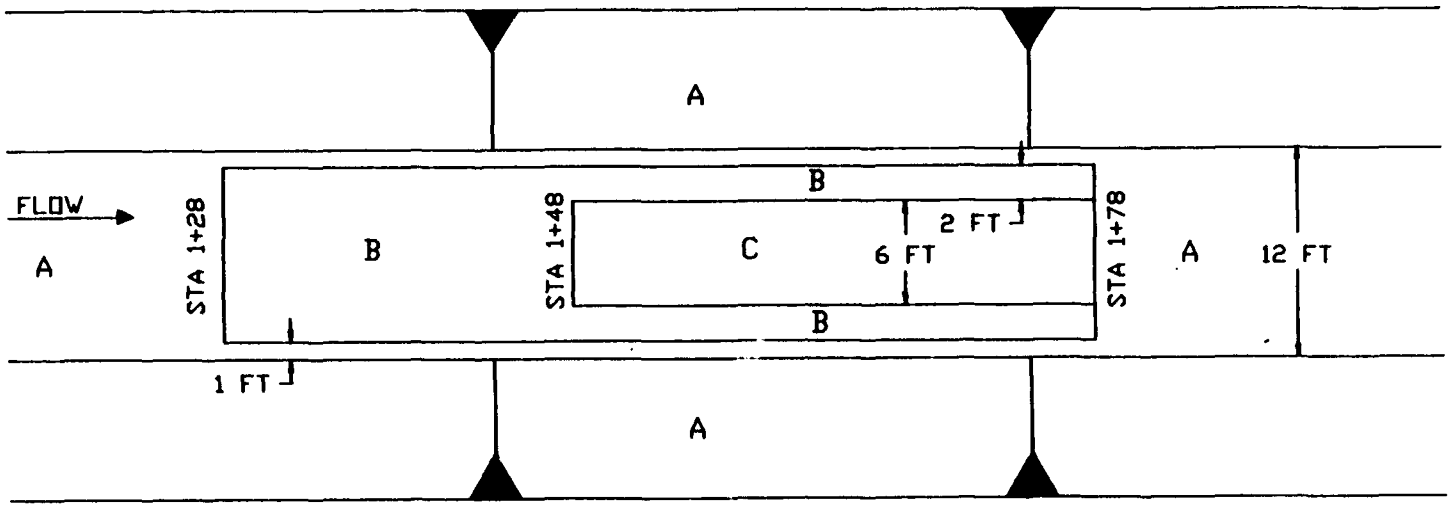


WHERE C_T = CORRECTION FOR THICKNESS

$$= \frac{D_{30} \text{ FOR THICKNESS OF } NT*}{D_{30} \text{ FOR THICKNESS OF } T*}$$

$T* = 1D_{100}$ OR $1.5D_{50}$, WHICHEVER IS GREATER

CORRECTION FOR VERTICAL VELOCITY DISTRIBUTION IN BEND AND RIPRAP THICKNESS

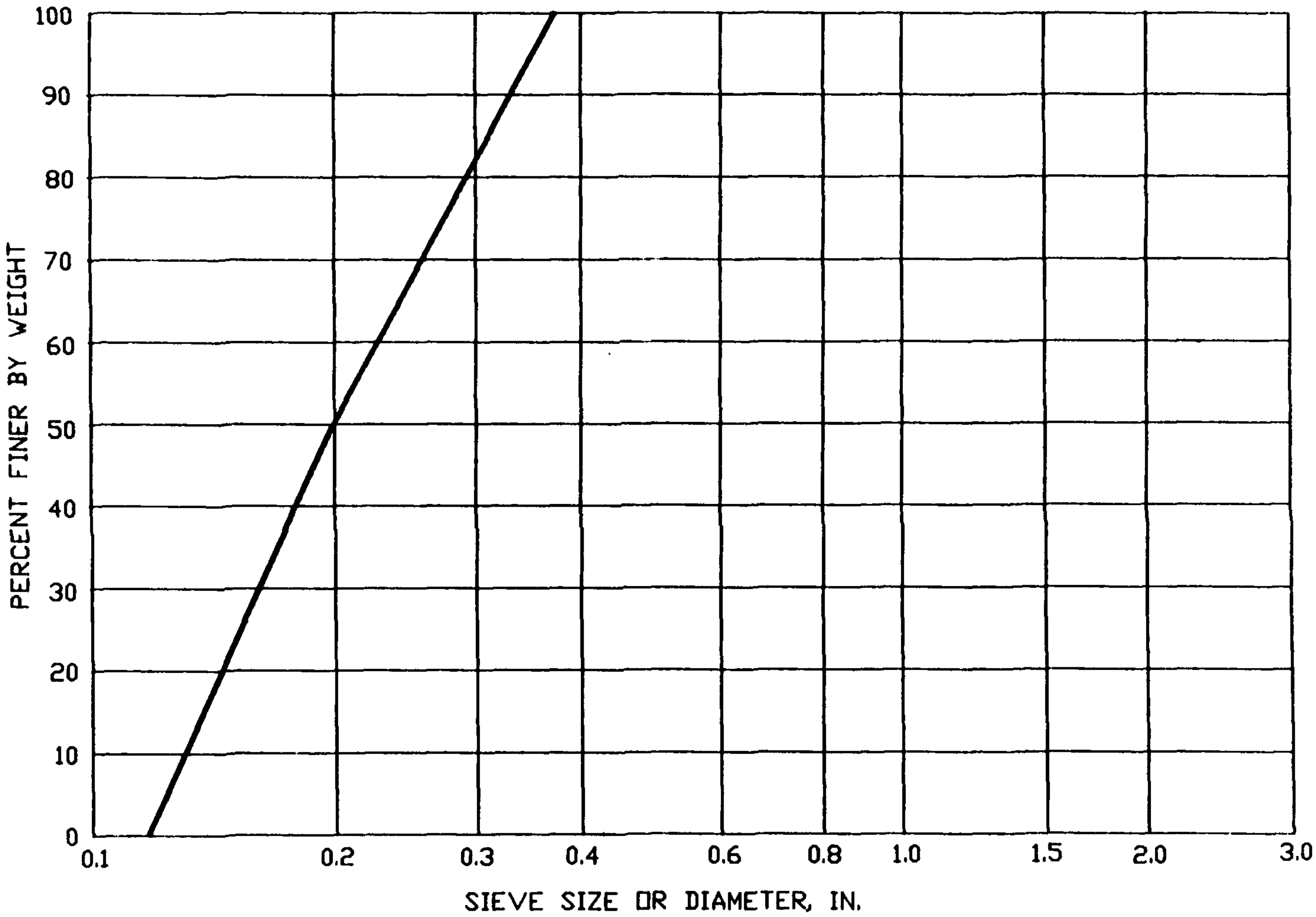


A = GRADATION 1

B = GRADATION 6 WITH LIGHT CEMENT COAT

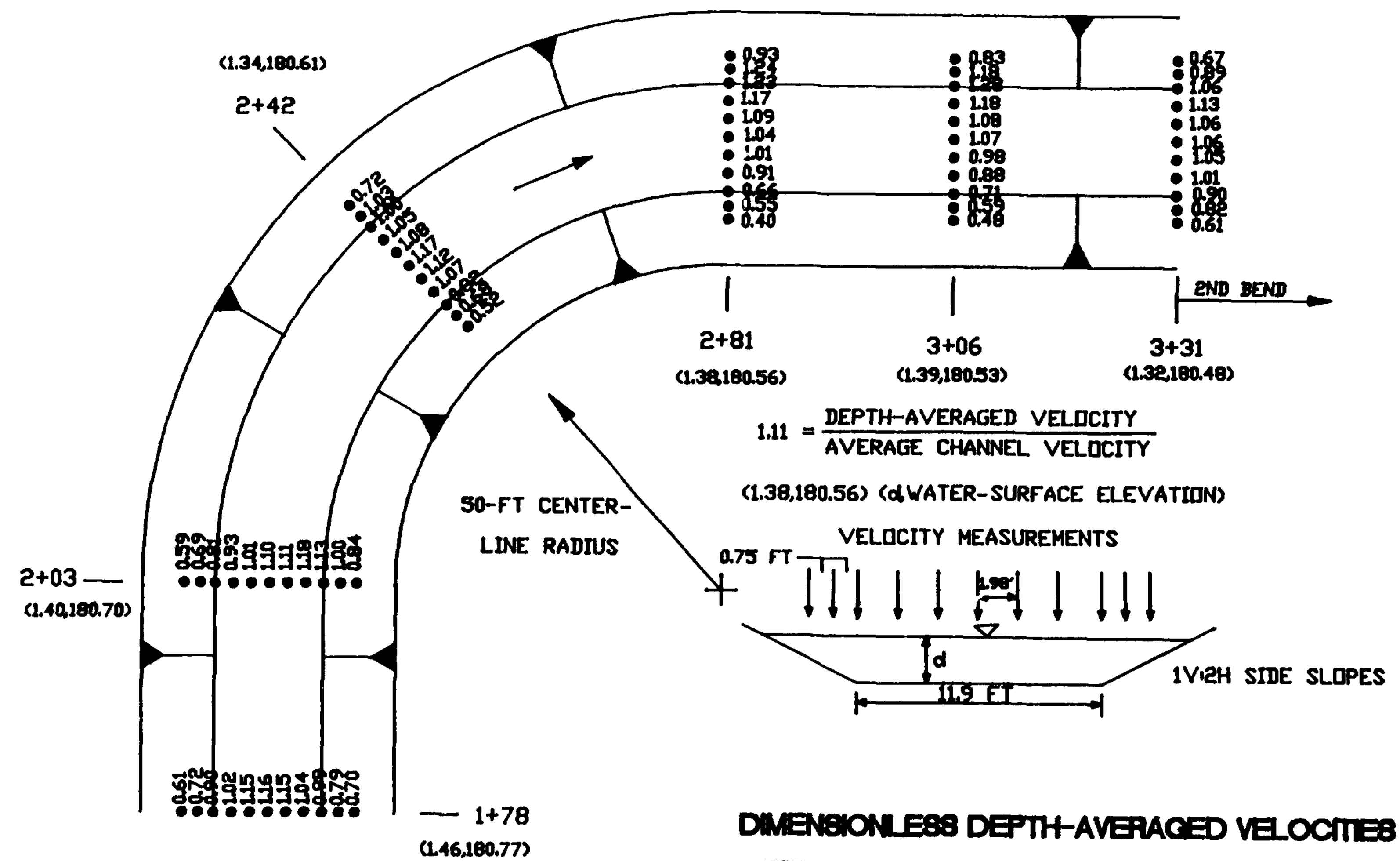
C = GRADATION 6, TEST SECTION

SCHEMATIC FOR BOTTOM RIPRAP TESTS



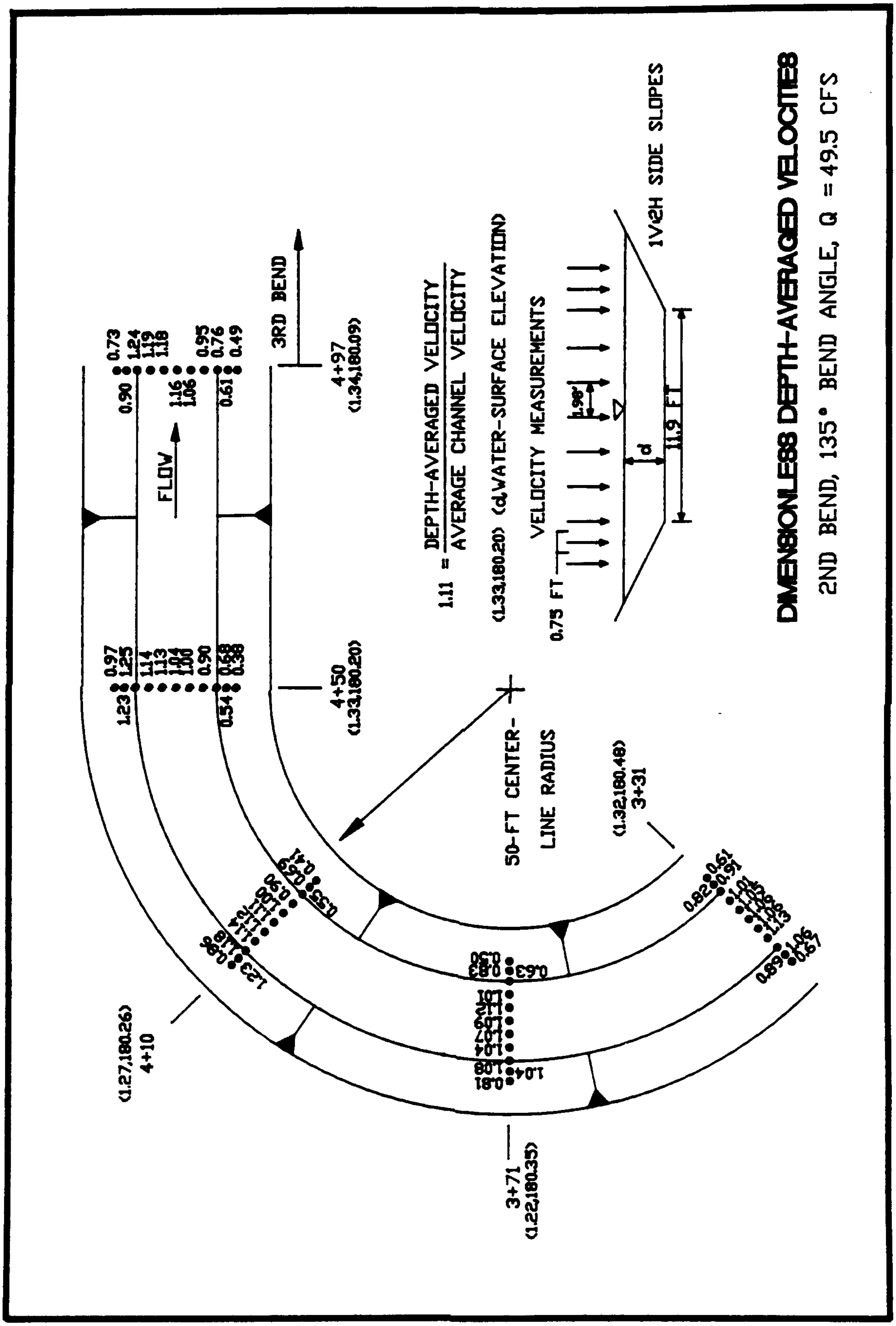
FILTER ROCK FOR GRADATION 2

APPENDIX A: VELOCITIES



DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

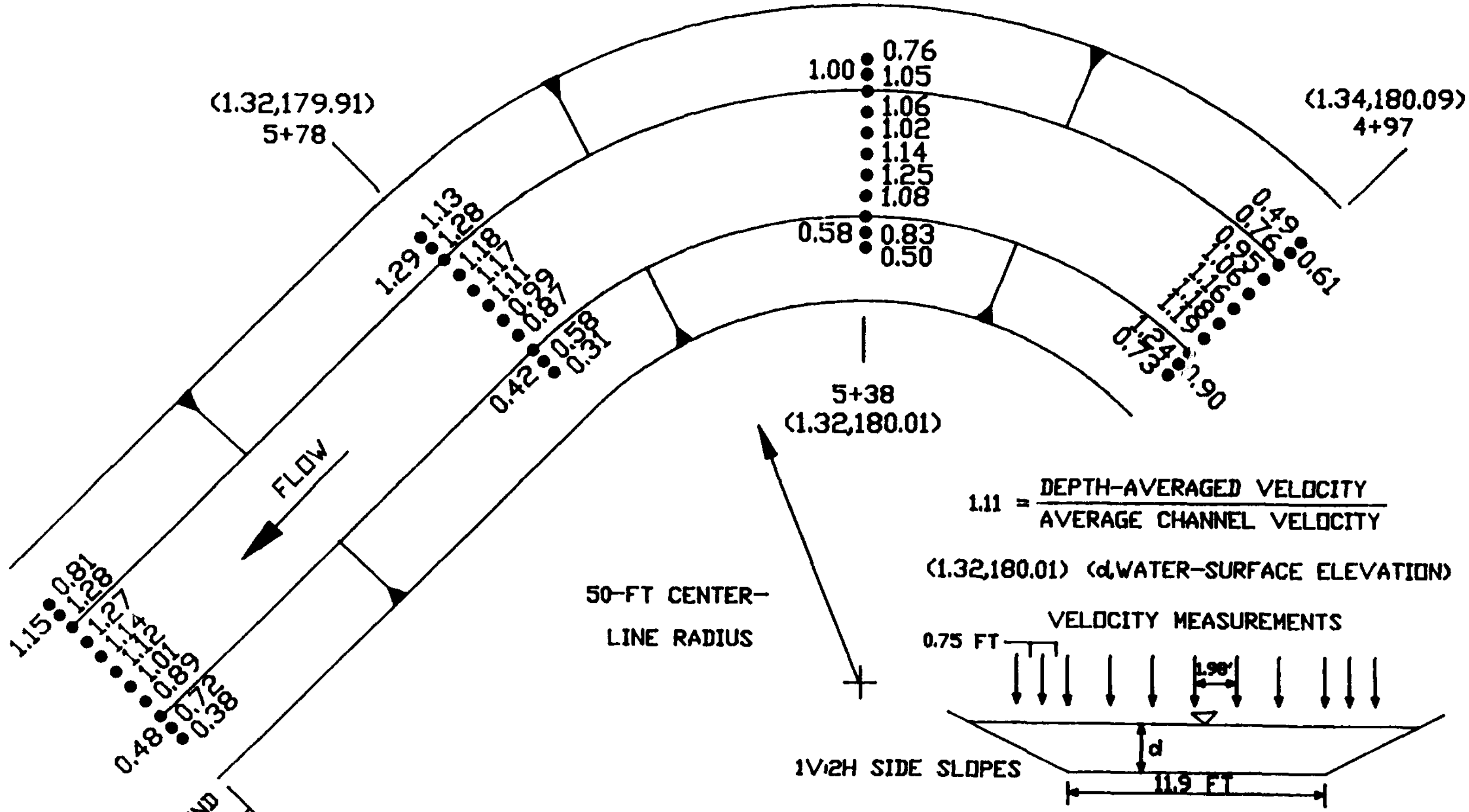
FIRST BEND, 90° BEND ANGLE, Q = 49.5 CFS



DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

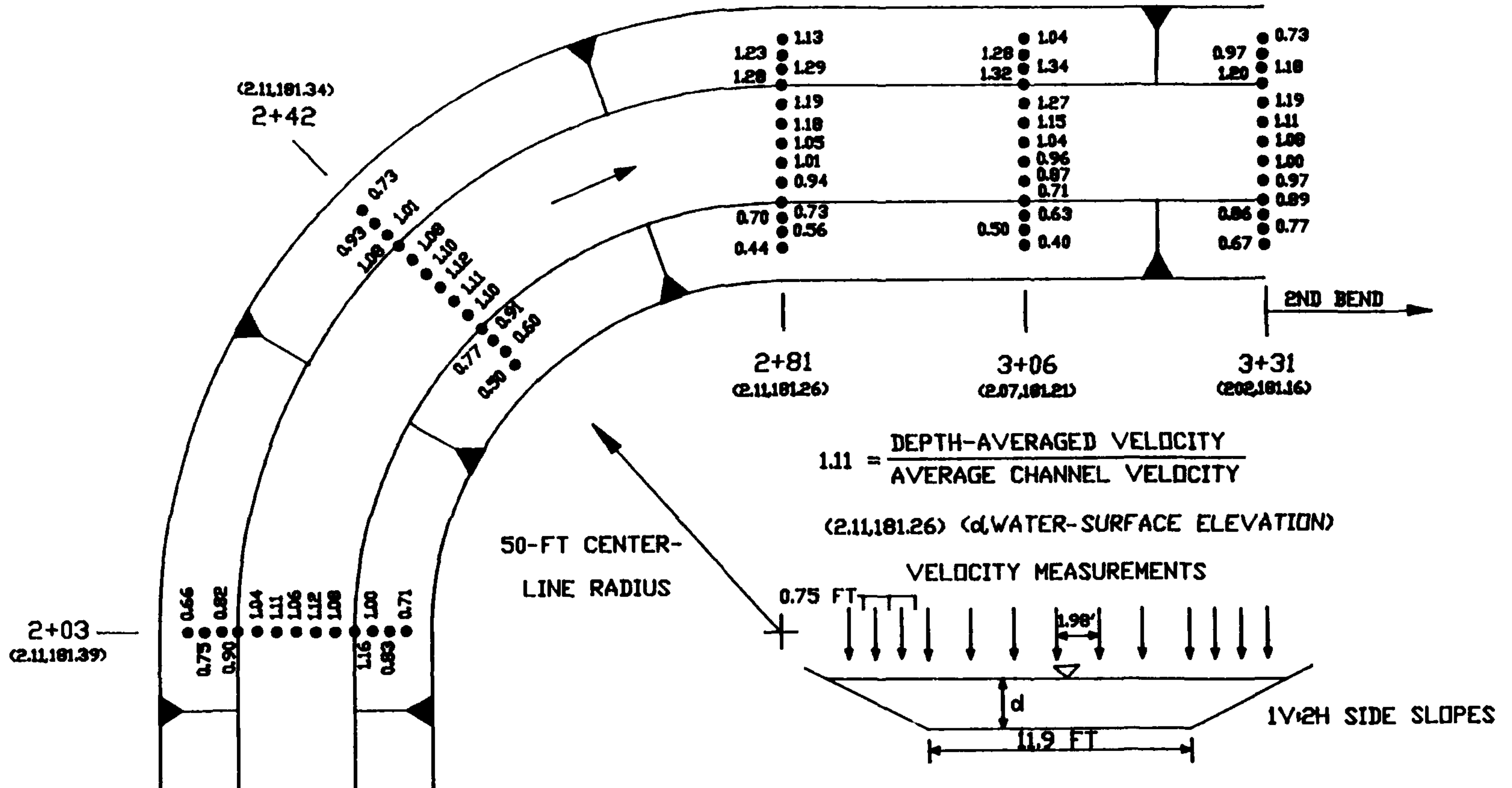
2ND BEND, 135° BEND ANGLE, Q = 49.5 CFS

PLATE A2



DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

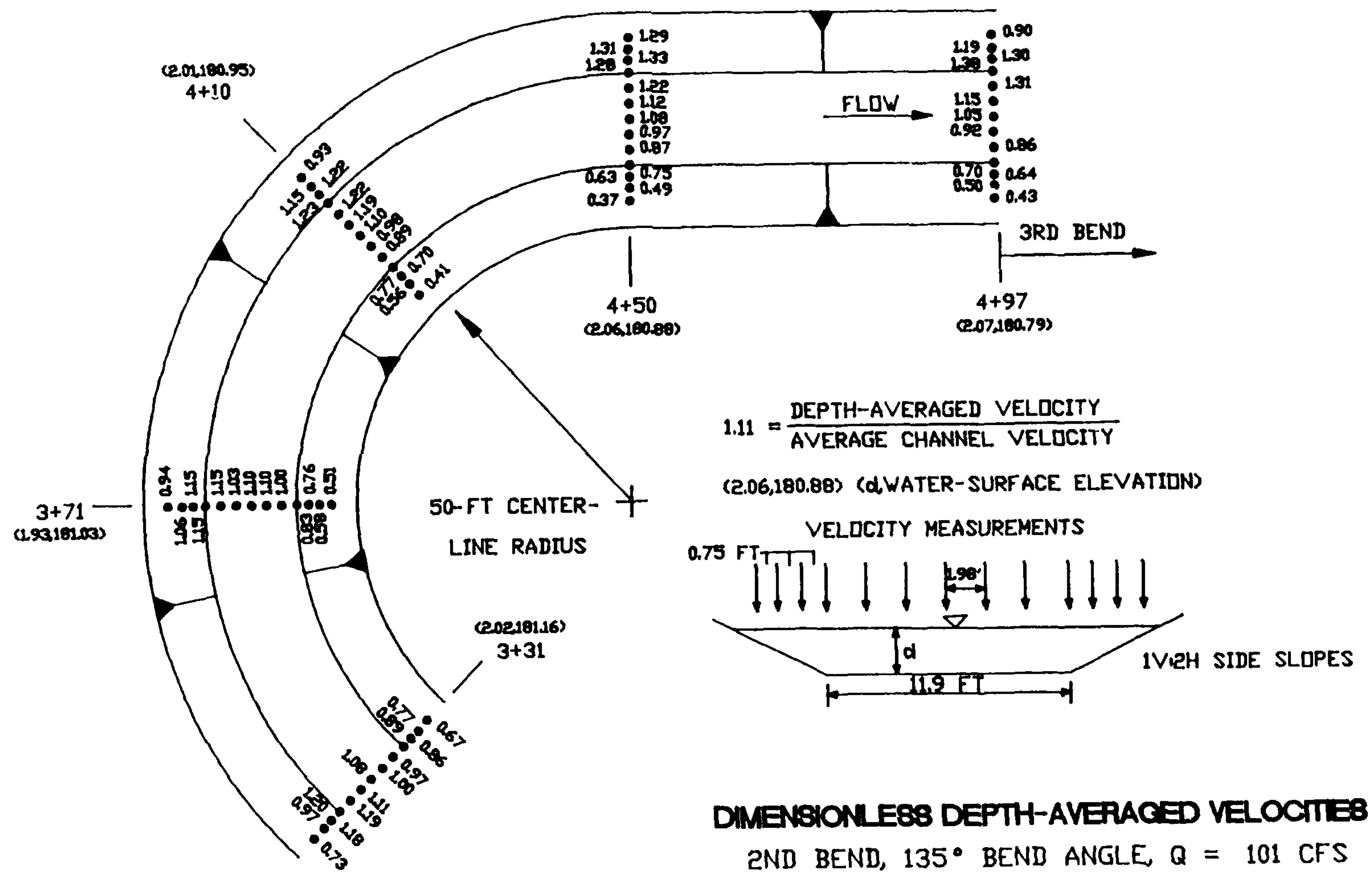
3RD BEND, 90° BEND ANGLE, Q = 49.5 CFS



DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

FIRST BEND, 90° BEND ANGLE, Q = 101 CFS

PLATE A4



DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

2ND BEND, 135° BEND ANGLE, Q = 101 CFS

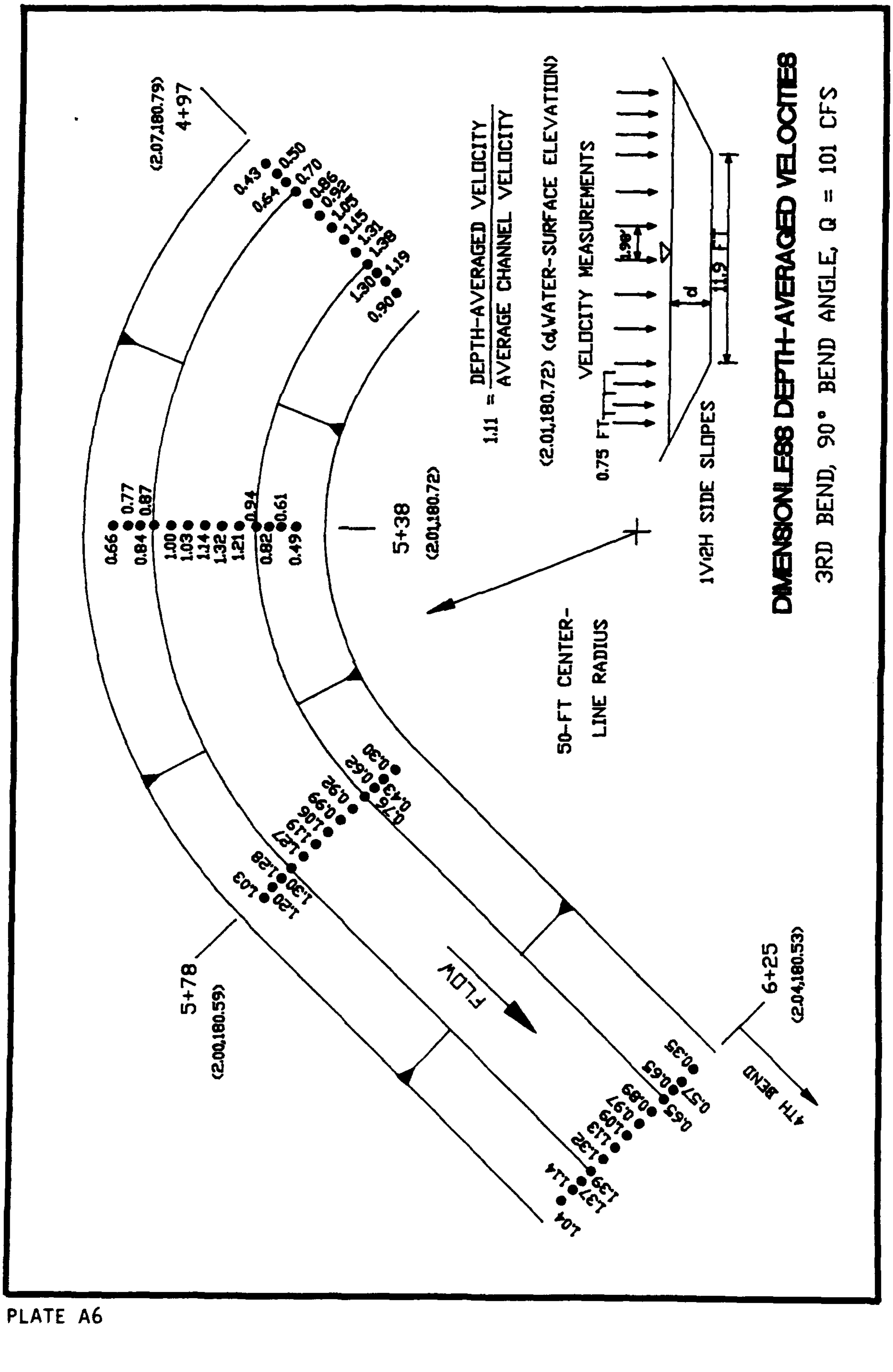
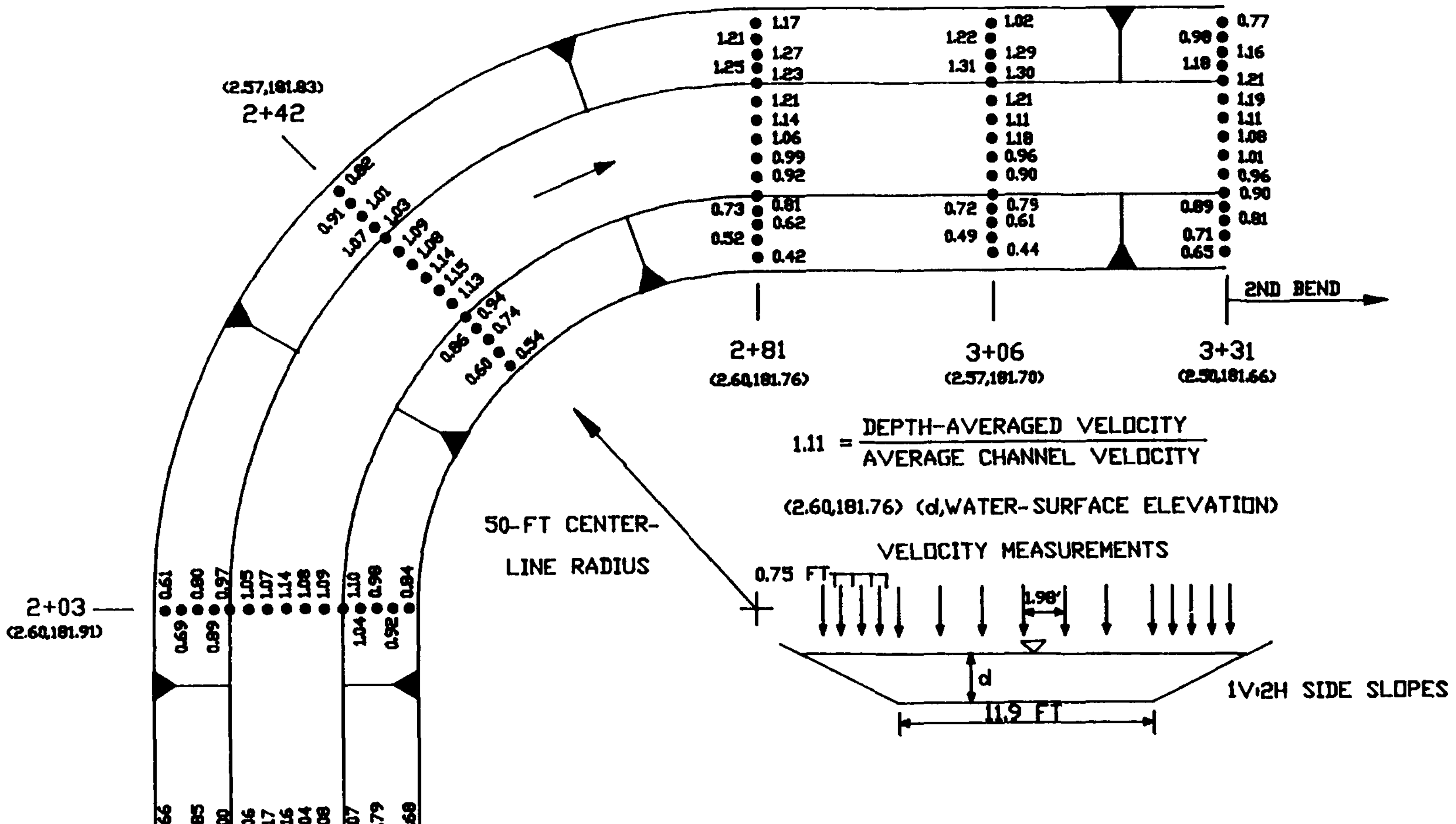
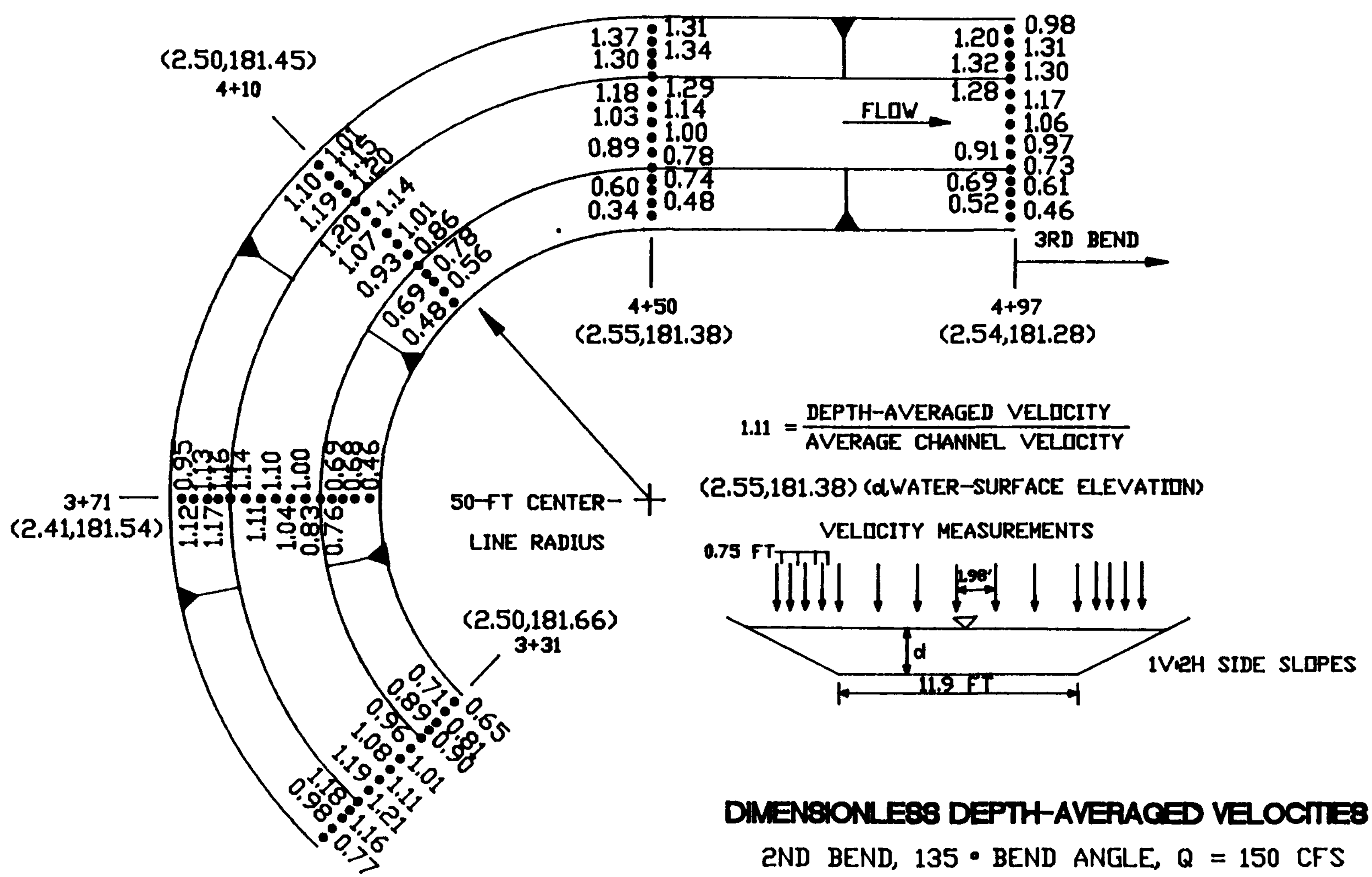

DIMENSIONLESS DEPTH-AVERAGED VELOCITIES
3RD BEND, 90° BEND ANGLE, Q = 101 CFS
1.11 = DEPTH-AVERAGED VELOCITY / AVERAGE CHANNEL VELOCITY
(2.01,180.72) (d,WATER-SURFACE ELEVATION)
VELOCITY MEASUREMENTS
0.75 FT
11.9 FT
d
1V:2H SIDE SLOPES
50-FT CENTER-LINE RADIUS
FLOW
4TH BEND
4+97
(2.07,180.79)
5+38
(2.01,180.72)
5+78
(2.00,180.59)
6+25
(2.04,180.53)
0.66
0.77
0.84
0.87
1.00
1.03
1.14
1.32
1.21
0.94
0.82
0.61
0.49

PLATE A6



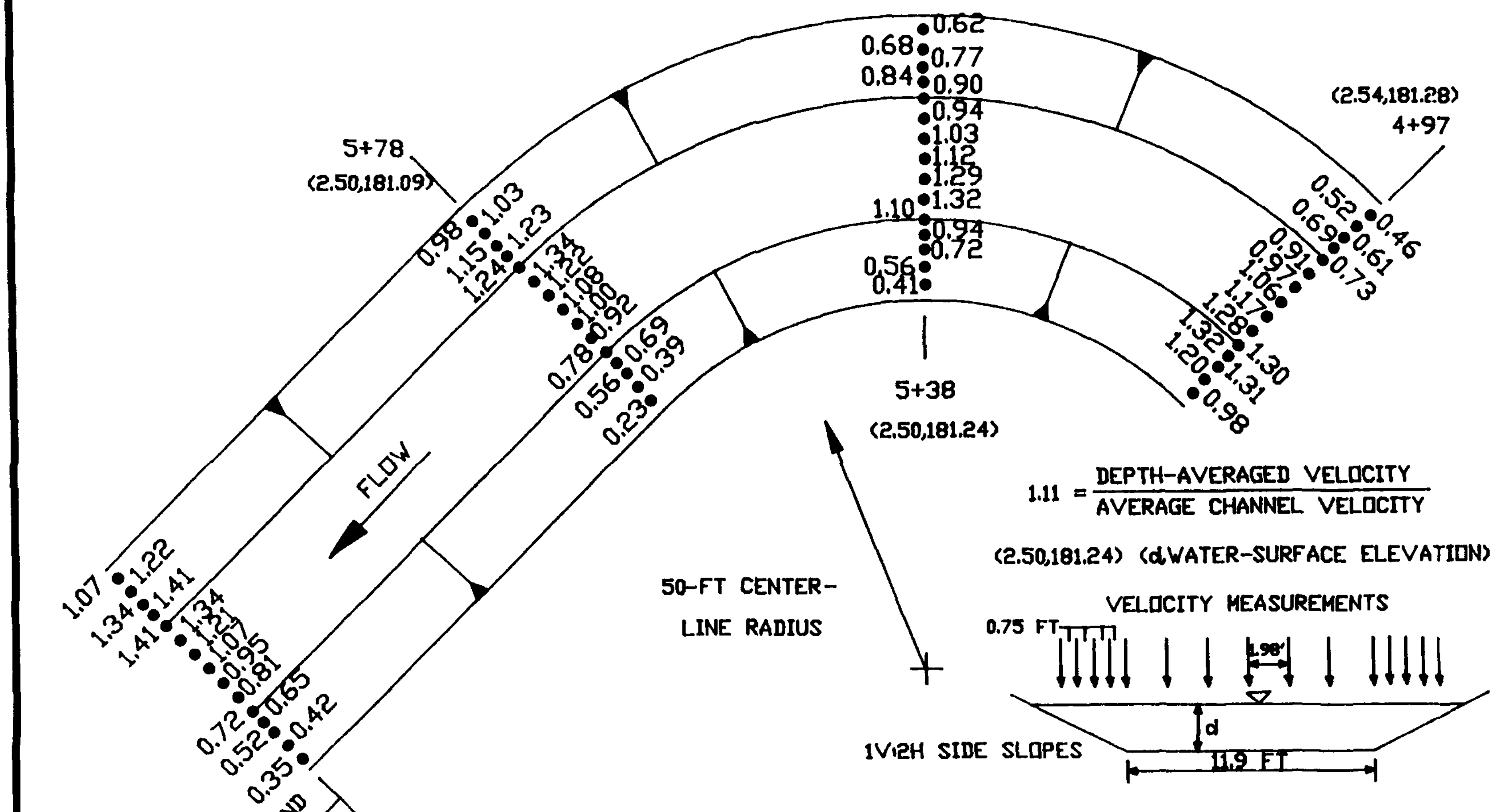
DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

FIRST BEND, 90 ° BEND ANGLE, Q = 150 CFS



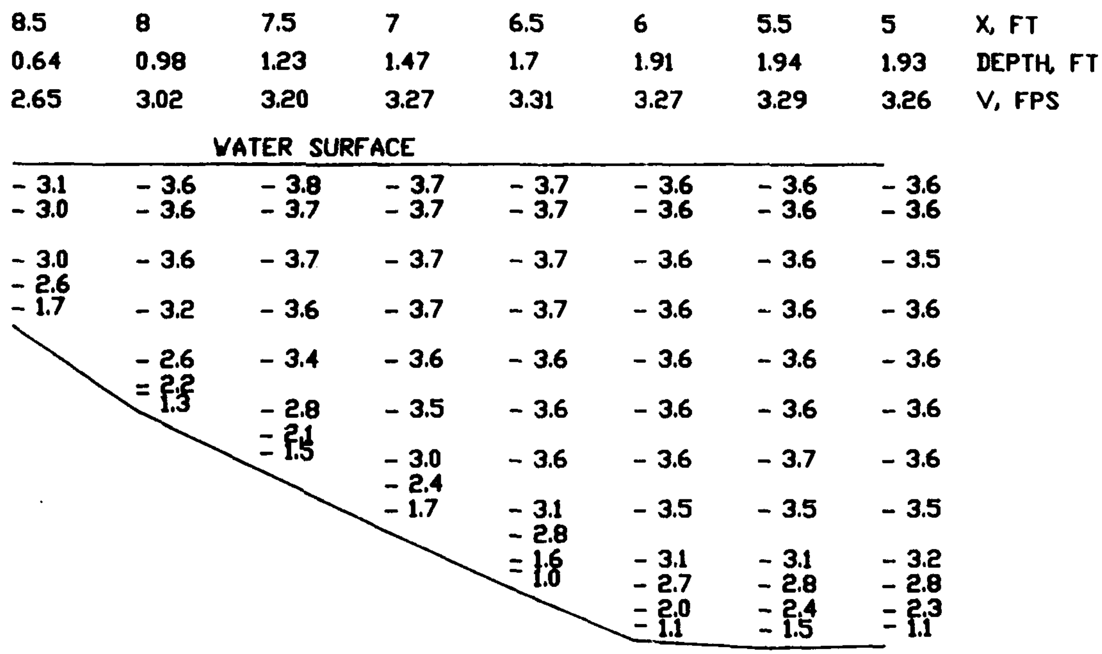
DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

2ND BEND, 135 ° BEND ANGLE, Q = 150 CFS



DIMENSIONLESS DEPTH-AVERAGED VELOCITIES

3RD BEND, 90° BEND ANGLE, Q = 150 CFS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

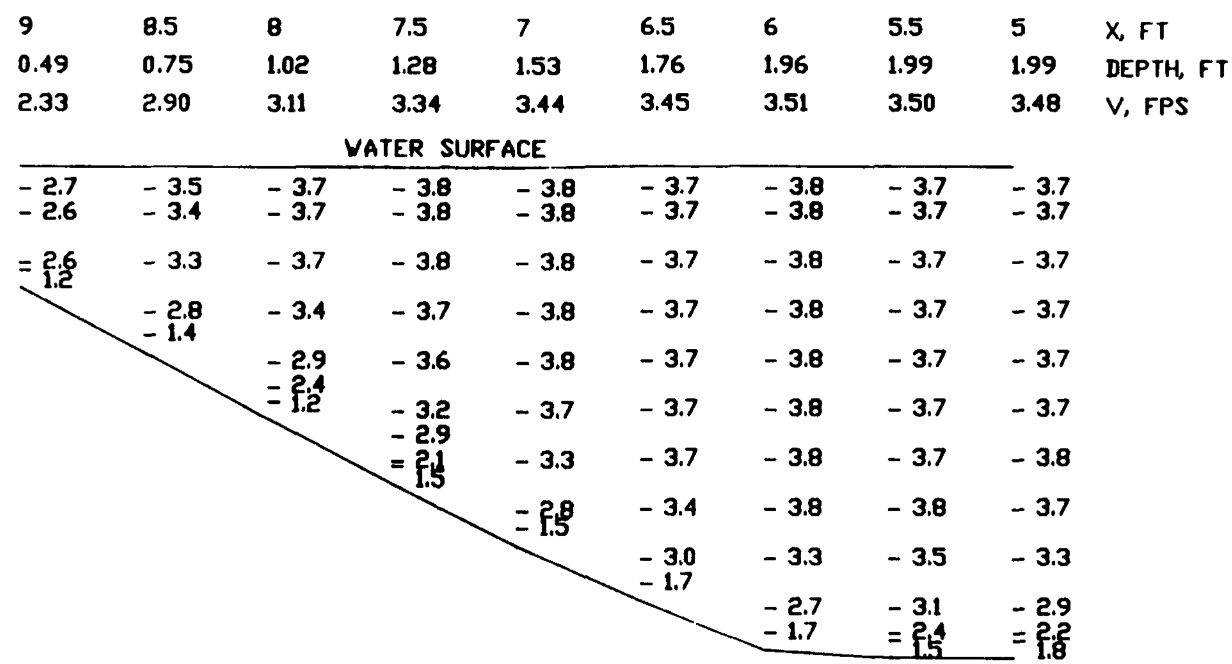
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.926

SIDE SLOPE VELOCITIES

TEST 702S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

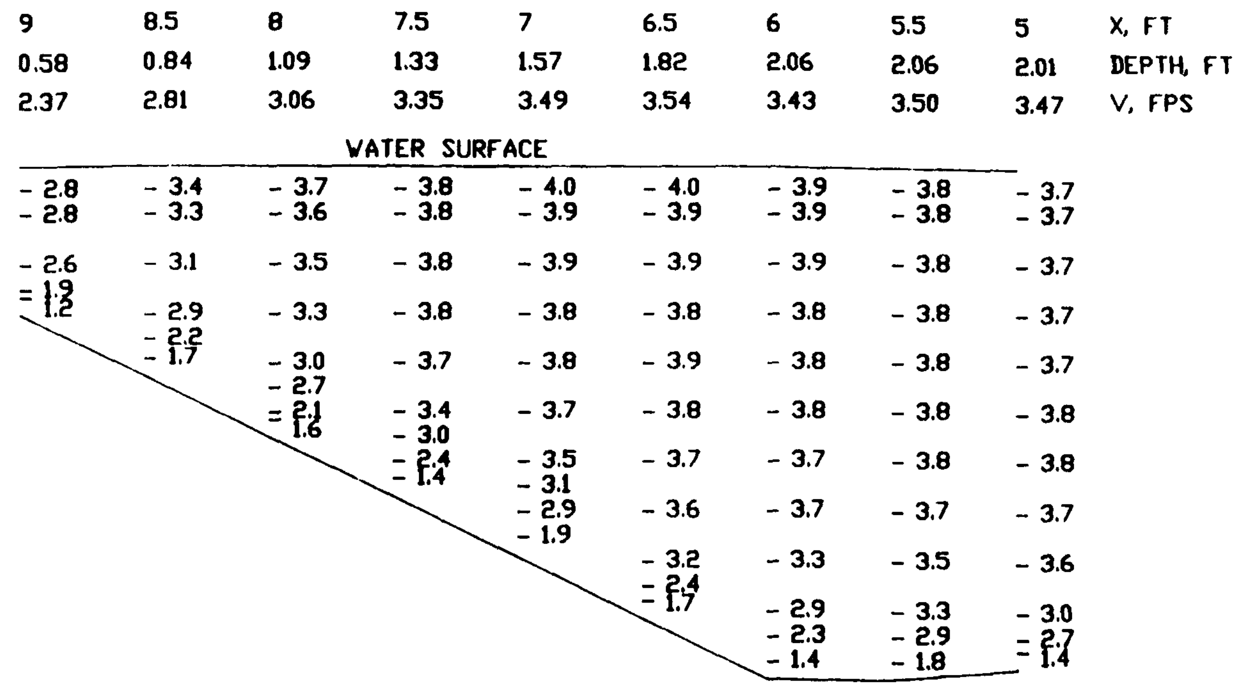
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.011

SIDE SLOPE VELOCITIES

TEST 752S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

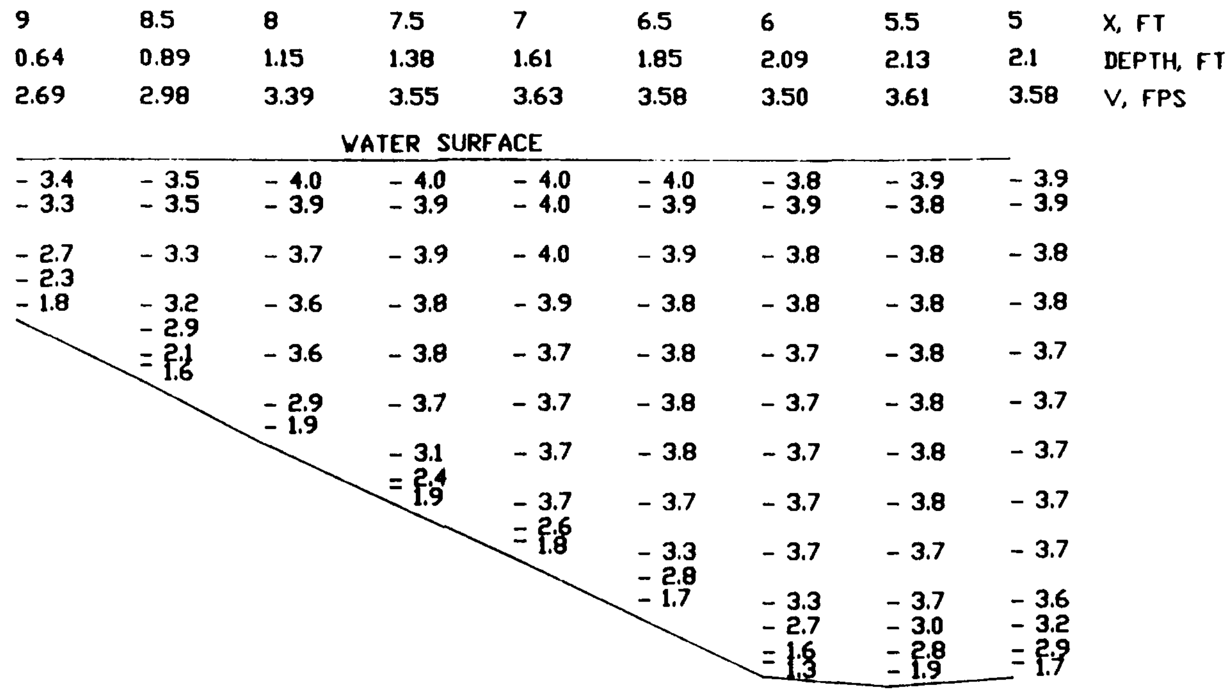
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.076

SIDE SLOPE VELOCITIES

TEST 802S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.146

SIDE SLOPE VELOCITIES

TEST A852S2812

X, FT	9	8.5	8	7.5	7	6.5	6	5.5	5
DEPTH, FT	0.65	0.90	1.16	1.41	1.65	1.9	2.13	2.16	2.13
V, FPS	2.57	3.08	3.35	3.55	3.59	3.58	3.59	3.60	3.57
WATER SURFACE									
	- 3.0	- 3.6	- 3.8	- 3.9	- 3.9	- 3.8	- 3.9	- 3.9	- 3.9
	- 2.9	- 3.5	- 3.8	- 3.8	- 3.8	- 3.9	- 3.8	- 3.9	- 3.9
	- 2.8	- 3.4	- 3.7	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8
	- 2.5								
	- 1.9	- 3.2	- 3.6	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8
		- 3.0							
		- 2.7	- 3.6	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8
		- 1.9							
			- 3.4						
			- 2.9	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8	- 3.8
			- 1.8						
				- 3.3	- 3.7	- 3.8	- 3.8	- 3.8	- 3.7
				- 2.7					
				- 1.8					
					- 3.6	- 3.7	- 3.8	- 3.8	- 3.7
					- 3.2				
					- 1.8	- 3.5	- 3.7	- 3.7	- 3.7
						- 3.0			
						- 2.5	- 3.5	- 3.6	- 3.6
						- 1.7			
							- 3.3	- 3.4	- 3.4
							- 2.7	- 2.8	- 3.1
							- 1.6	- 2.0	- 1.4

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.196

SIDE SLOPE VELOCITIES

TEST 902S281.GR2

X, FT	8.5	8	7.5	7	6.5	6	5.5	5
DEPTH, FT	0.66	0.91	1.16	1.41	1.67	1.81	1.9	1.91
V, FPS	2.21	2.53	3.15	3.33	3.45	3.54	3.55	3.51

WATER SURFACE

- 2.7	- 3.2	- 3.7	- 3.9	- 3.9	- 3.9	- 3.9	- 3.8
- 2.7	- 3.0	- 3.7	- 3.9	- 3.9	- 3.9	- 3.9	- 3.8
- 2.4	- 2.8	- 3.7	- 3.9	- 3.9	- 3.9	- 3.9	- 3.8
- 2.0	- 2.6	- 3.6	- 3.7	- 3.9	- 3.9	- 3.9	- 3.8
- 1.3	- 2.2	- 3.1	- 3.6	- 3.9	- 3.9	- 3.9	- 3.9
	- 1.8	- 2.8	- 3.3	- 3.7	- 3.8	- 3.9	- 3.9
	- 1.3	- 2.3	- 2.7	- 3.5	- 3.7	- 3.8	- 3.9
		- 1.5	- 1.9	- 2.9	- 3.6	- 3.7	- 3.6
			- 1.7	- 2.3	- 2.9	- 3.1	- 3.1
				- 1.8	- 2.1	- 2.8	- 2.7
					- 1.5	- 2.2	- 2.2
						- 1.3	- 1.6

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

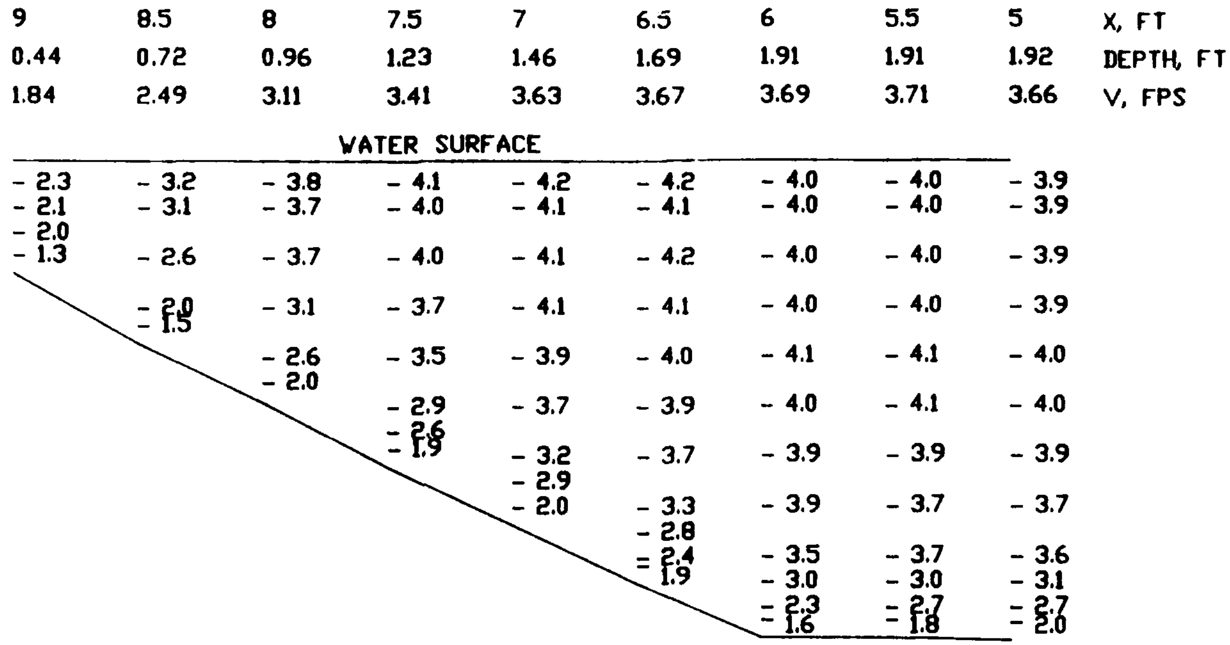
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.908

SIDE SLOPE VELOCITIES

TEST 702S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

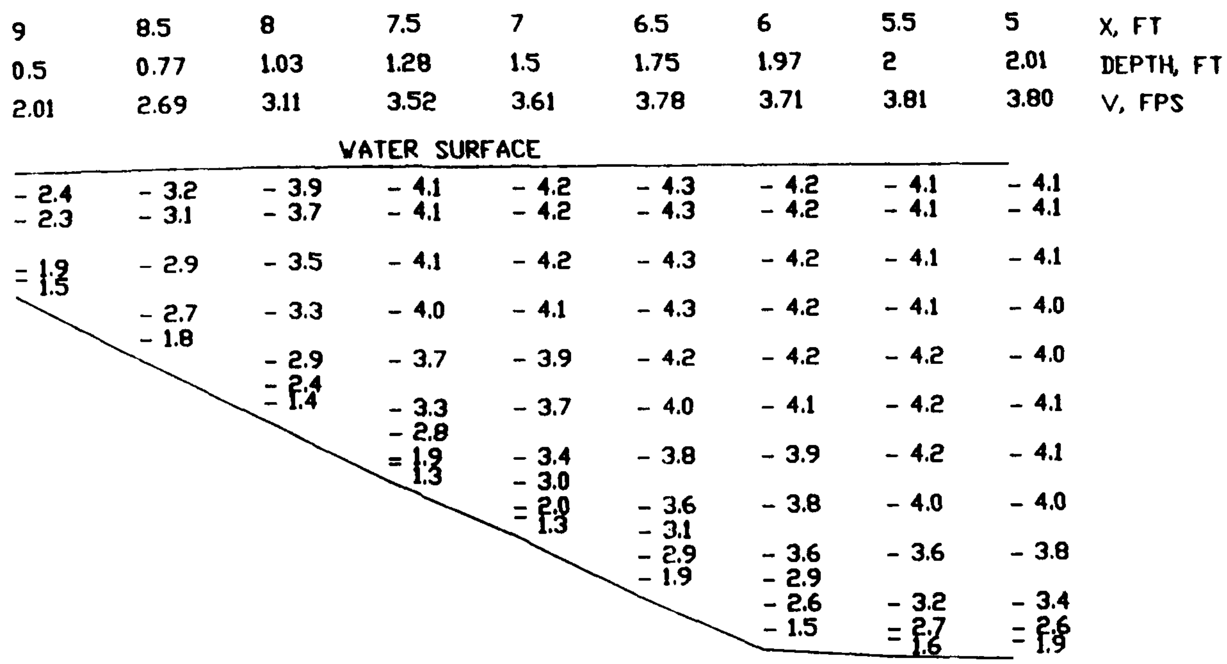
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.973

SIDE SLOPE VELOCITIES

TEST 752S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

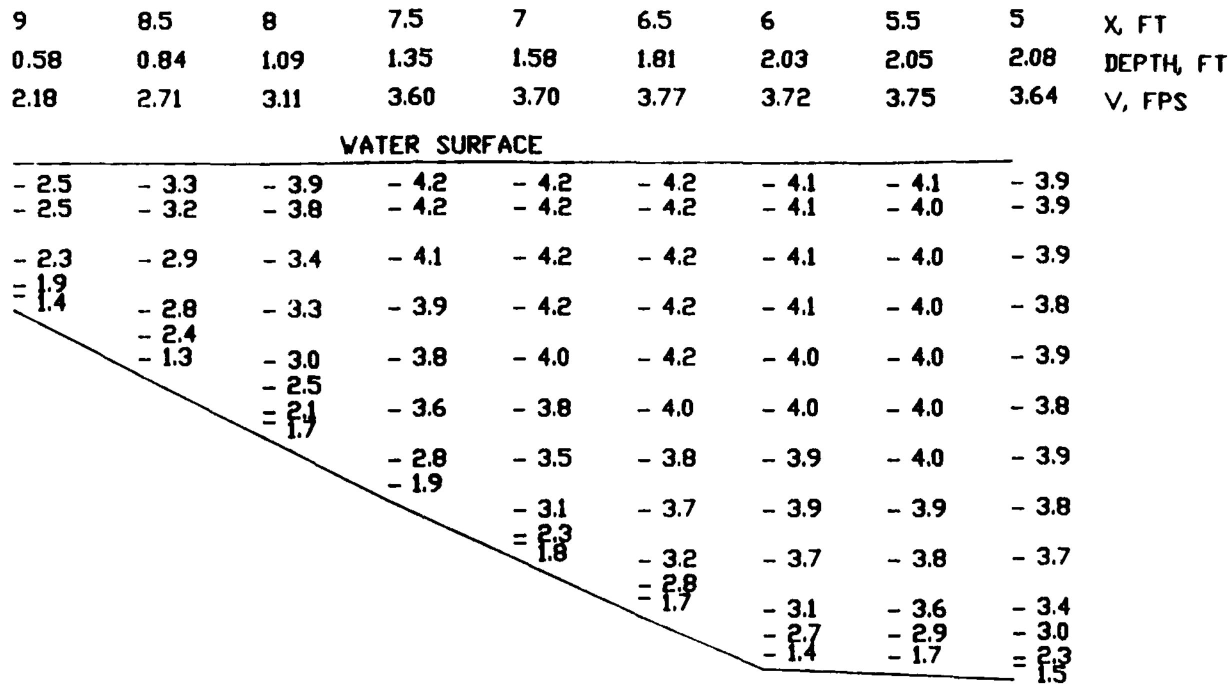
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.033

SIDE SLOPE VELOCITIES

TEST 802S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

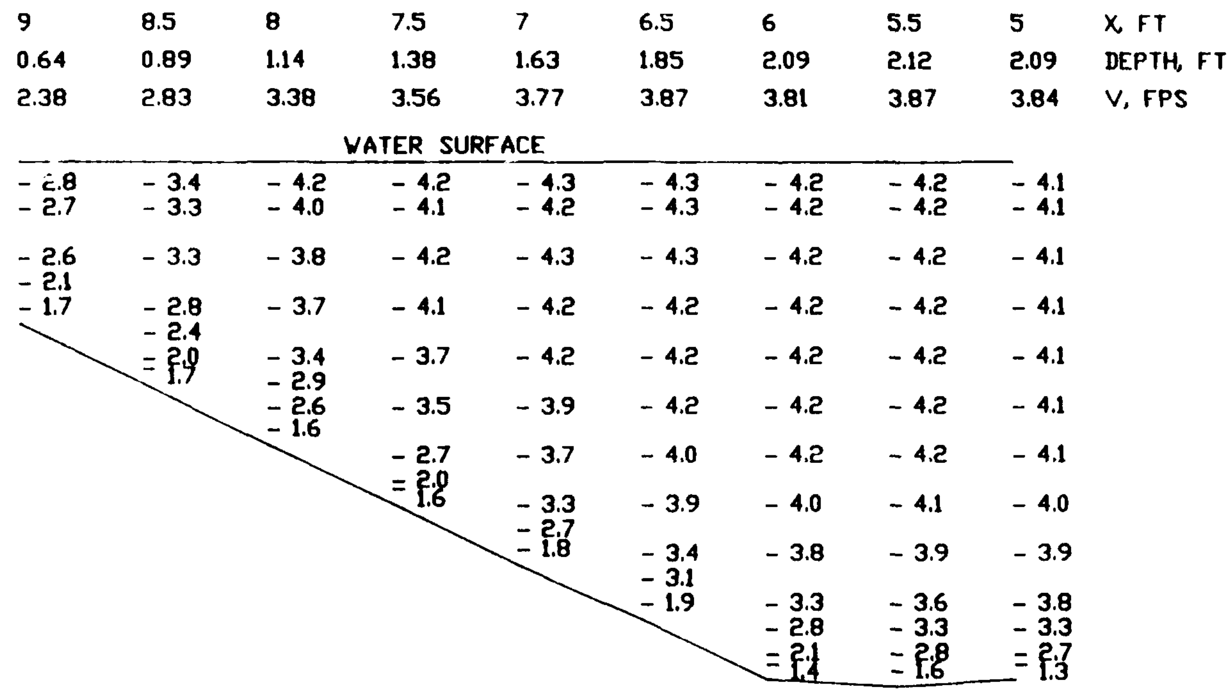
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.113

SIDE SLOPE VELOCITIES

TEST 852S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

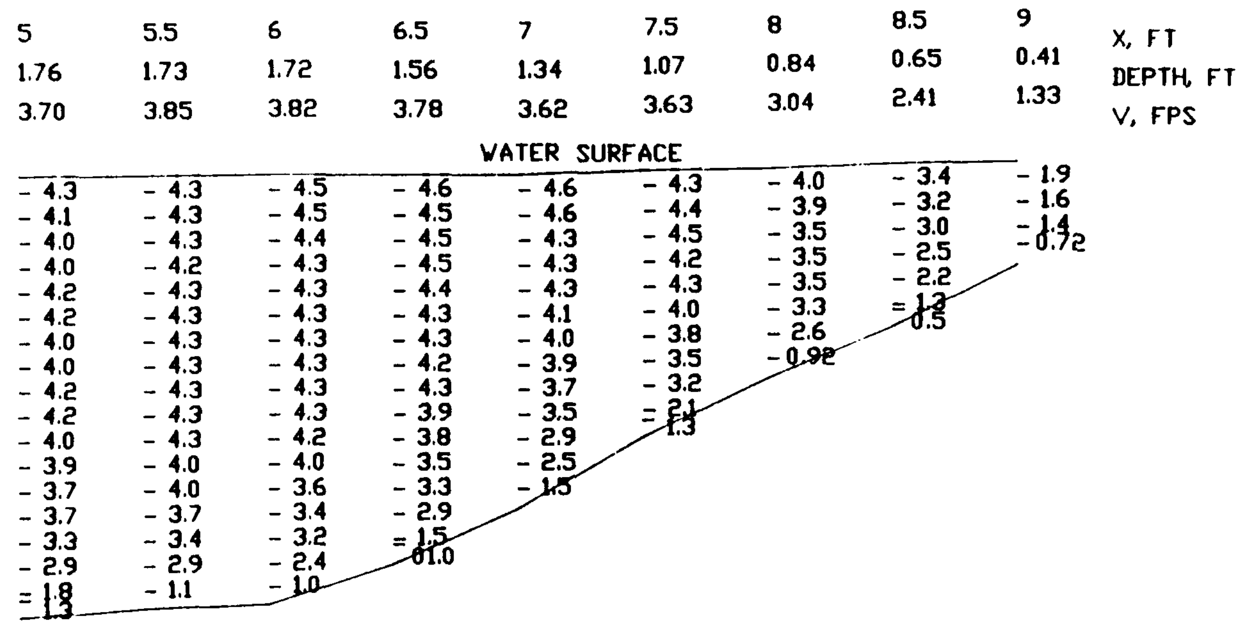
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.168

SIDE SLOPE VELOCITIES

TEST 902S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

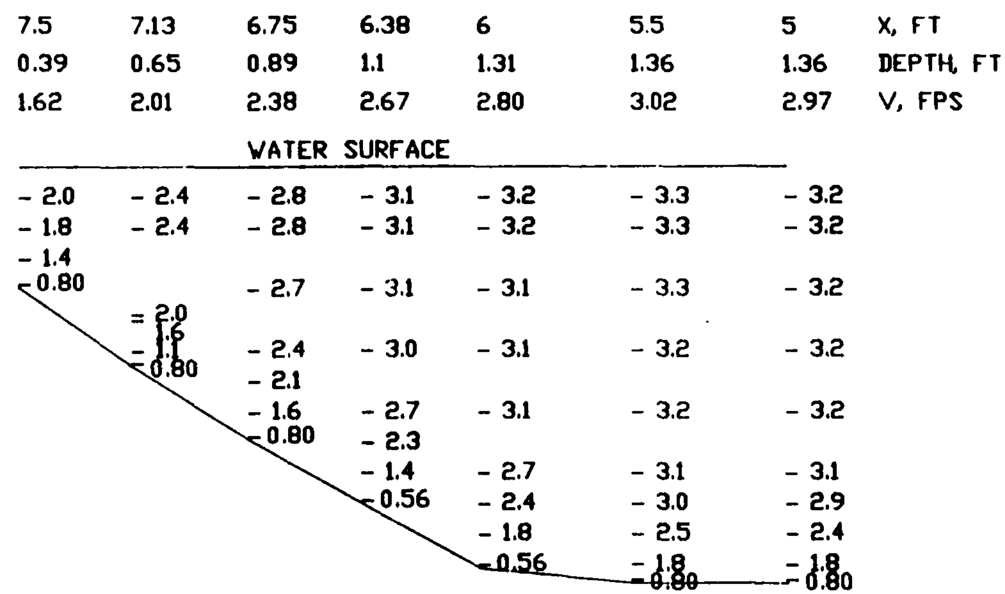
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.208

SIDE SLOPE VELOCITIES

TEST 702S578.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

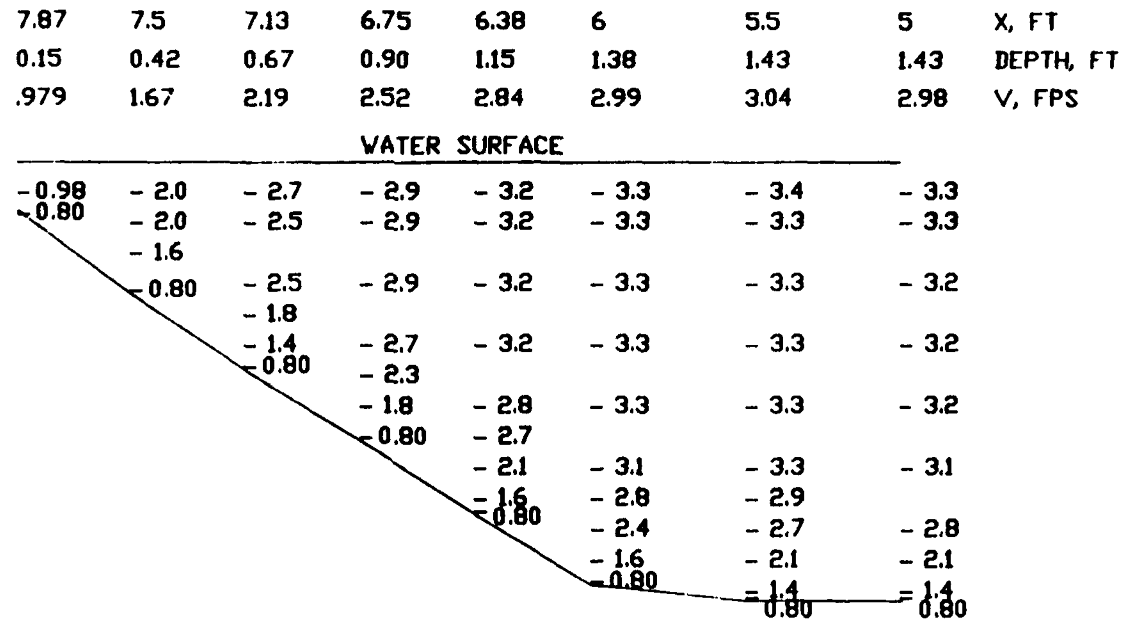
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.396

SIDE SLOPE VELOCITIES

TEST 4015S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

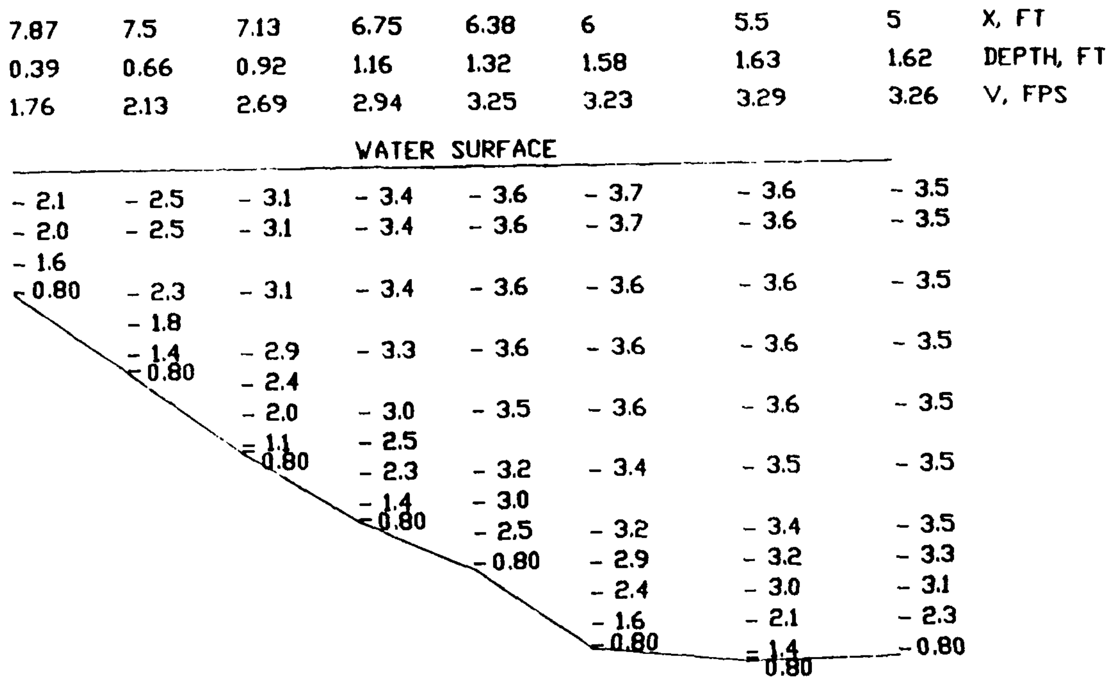
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.456

SIDE SLOPE VELOCITIES

TEST 4515S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

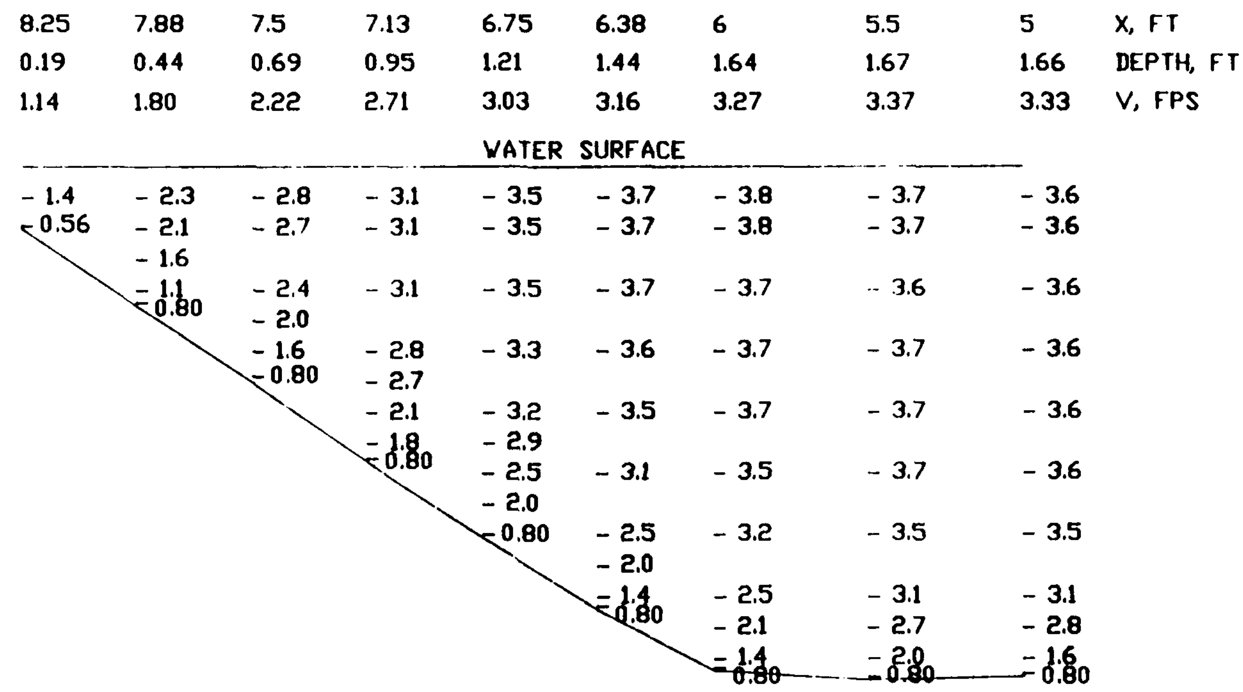
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.676

SIDE SLOPE VELOCITIES

TEST 5515S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

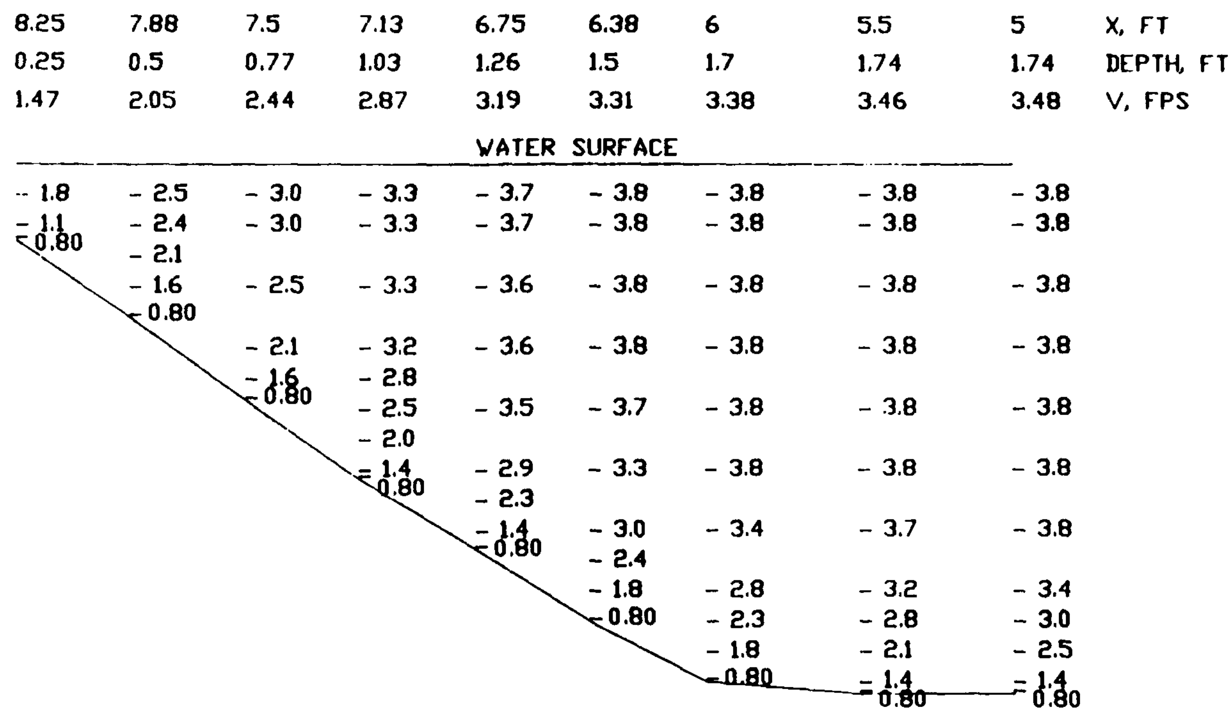
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.726

SIDE SLOPE VELOCITIES

TEST 6015S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

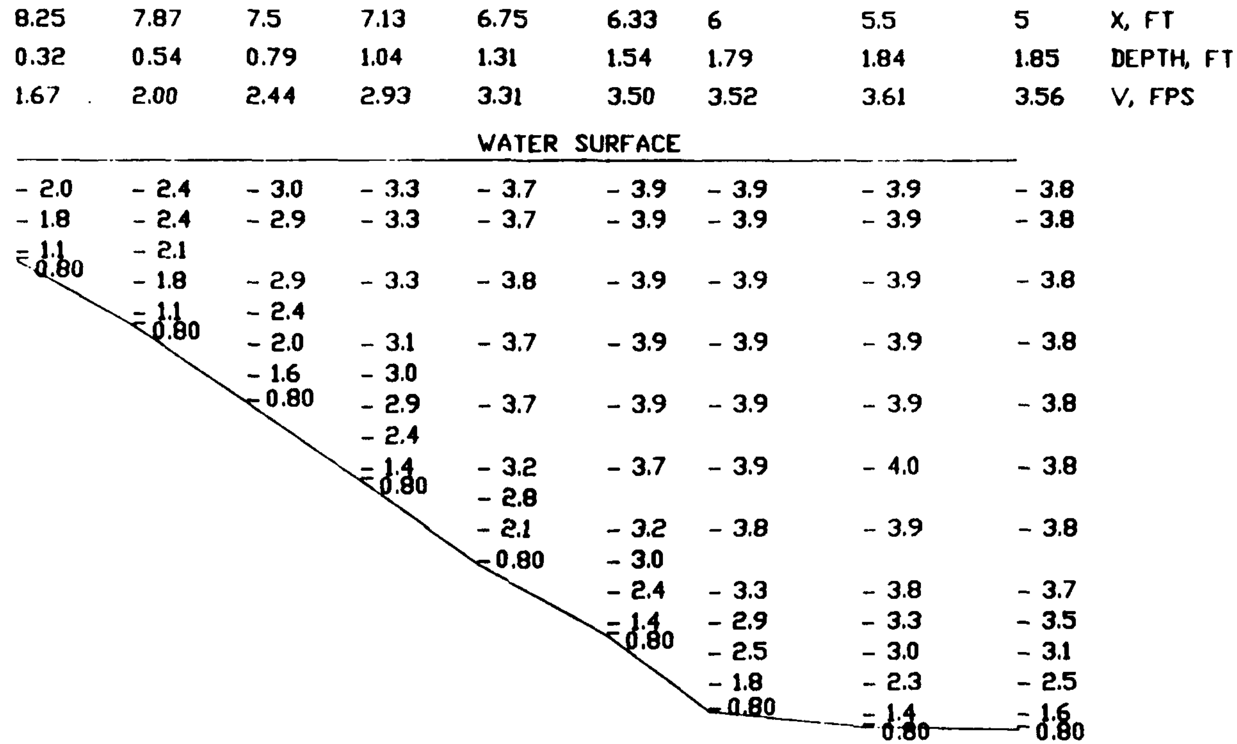
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVEF SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.776

SIDE SLOPE VELOCITIES

TEST 6515S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

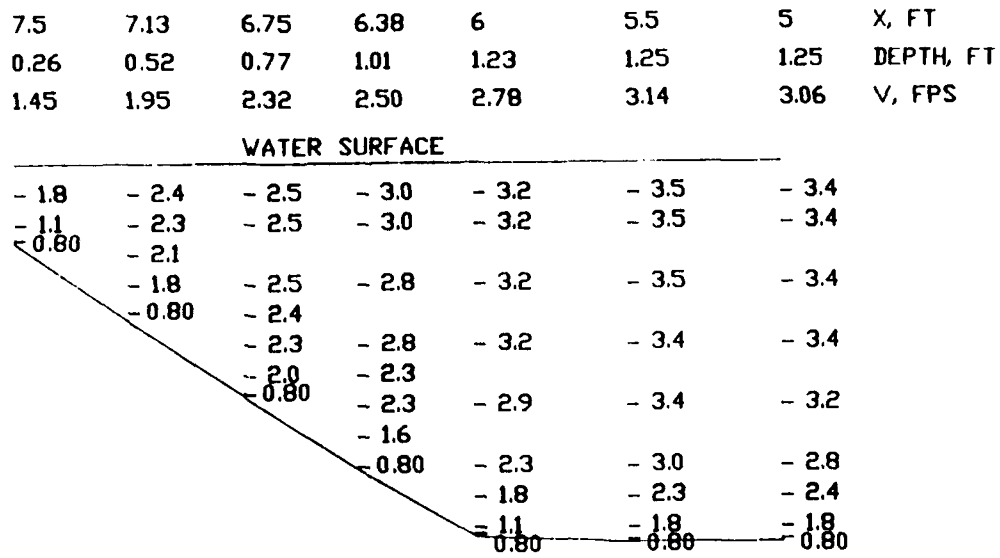
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.896

SIDE SLOPE VELOCITIES

TEST 7015S281.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

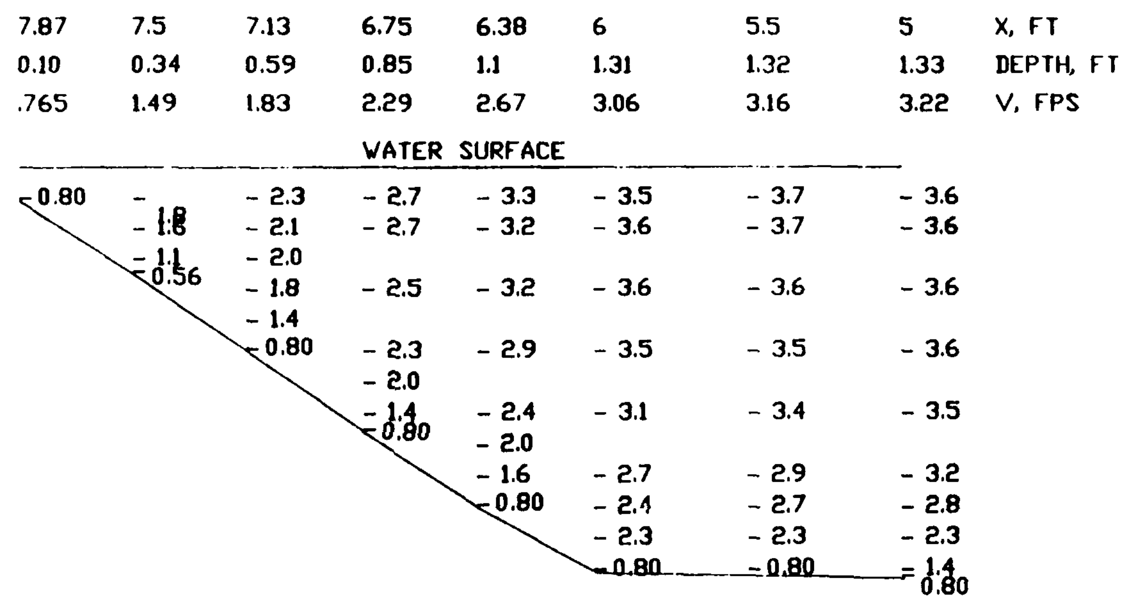
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.368

SIDE SLOPE VELOCITIES

TEST 4015S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

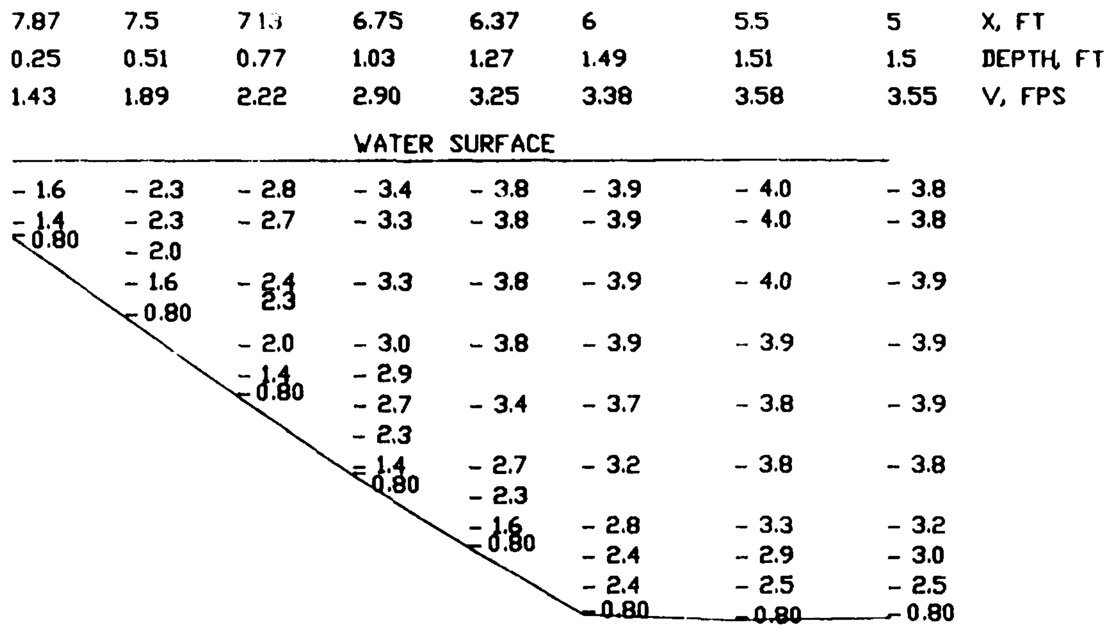
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.423

SIDE SLOPE VELOCITIES

TEST 4515S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

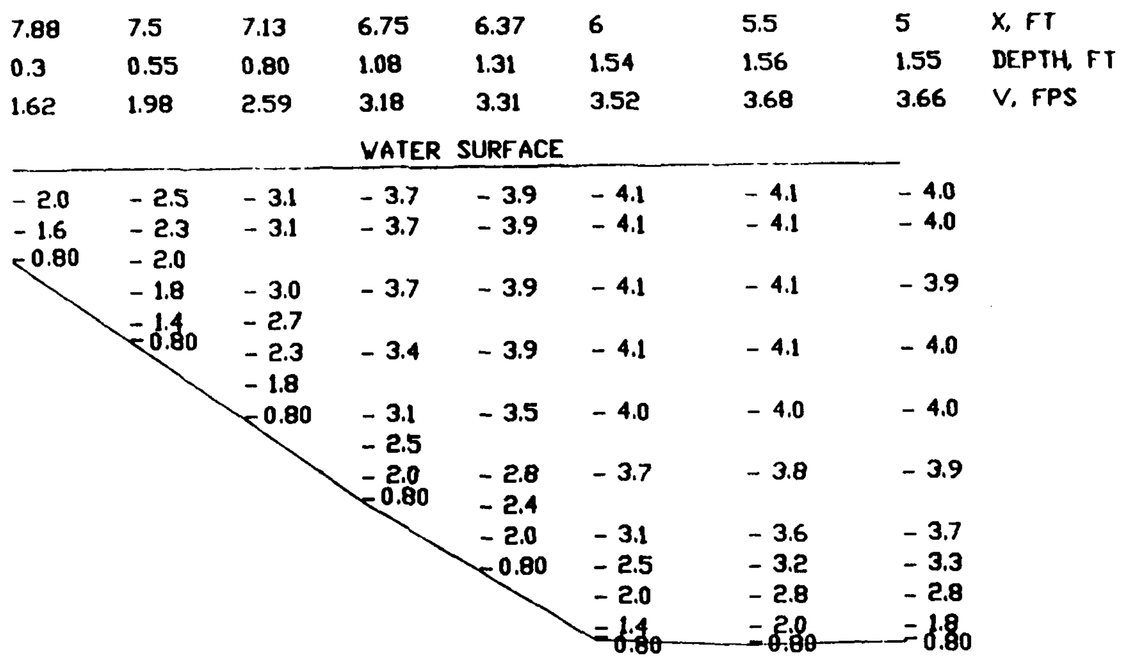
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.633

SIDE SLOPE VELOCITIES

TEST 5515S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

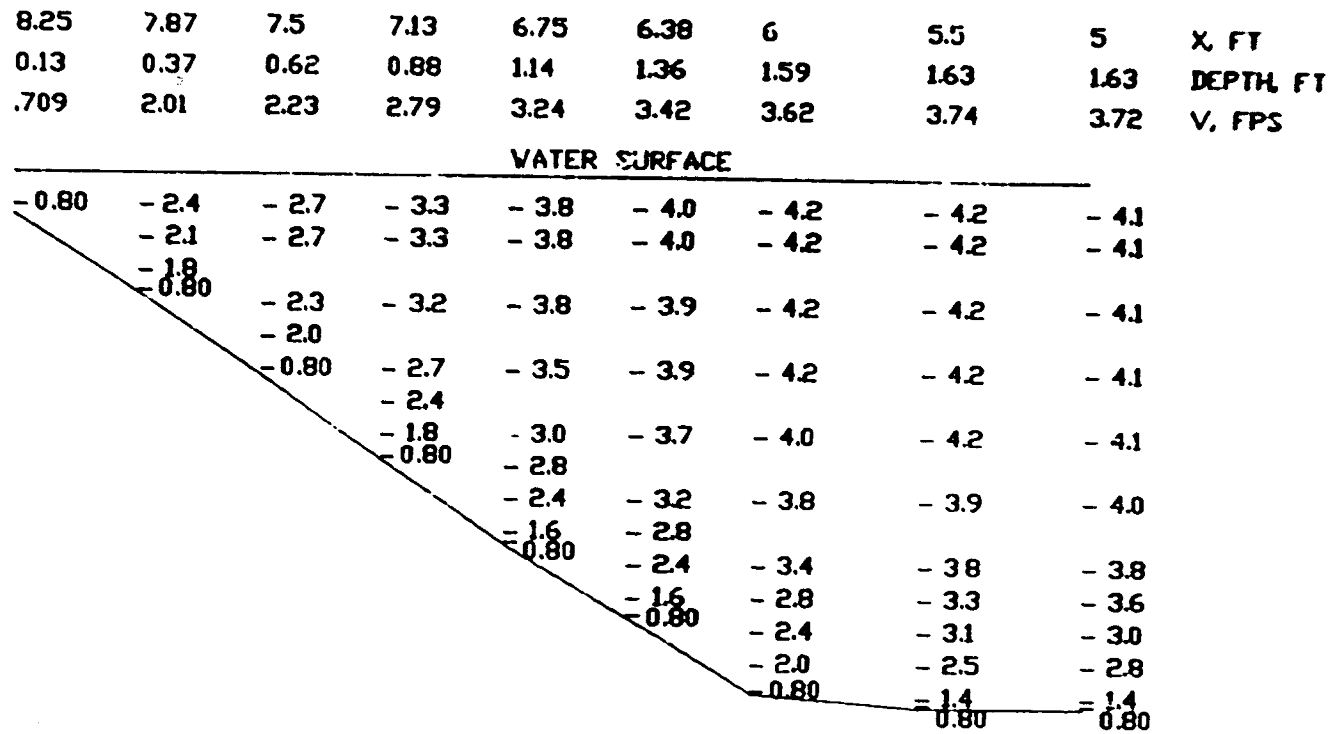
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.683

SIDE SLOPE VELOCITIES

TEST 6015S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

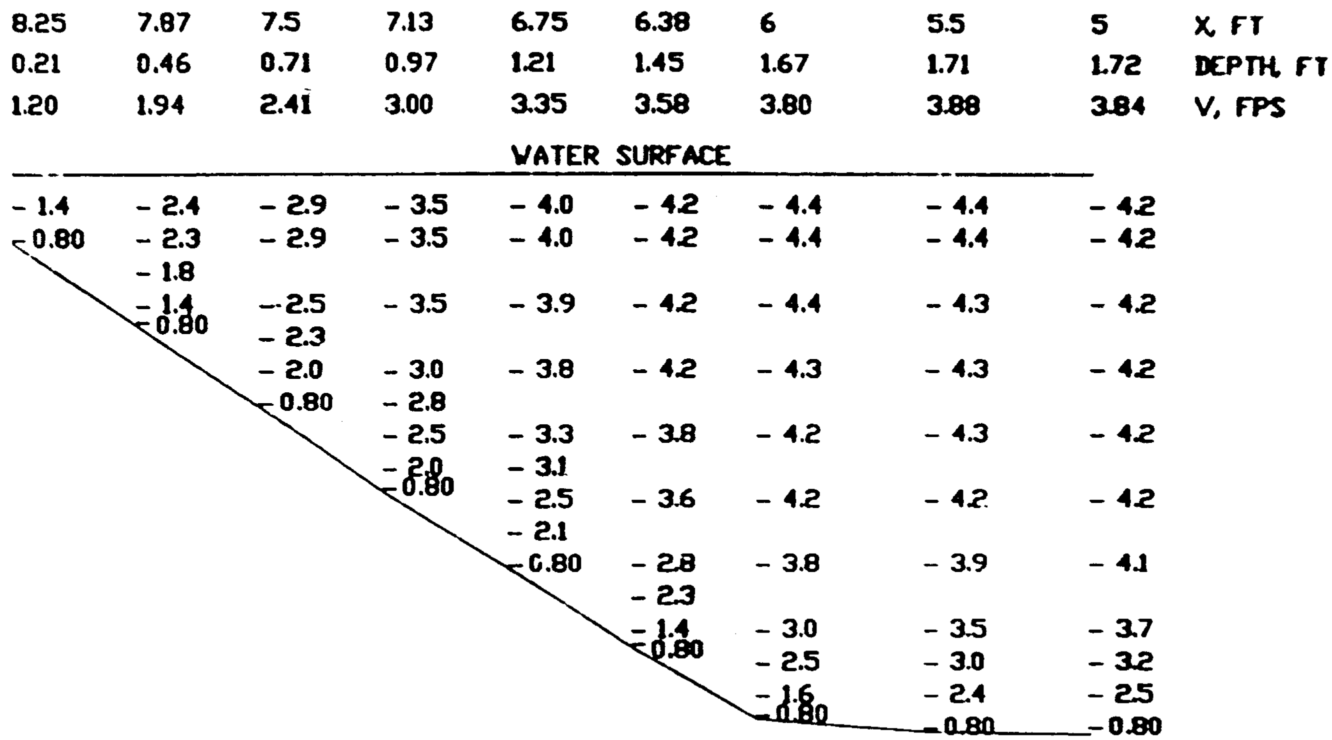
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.743

SIDE SLOPE VELOCITIES

TEST 6515S306.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

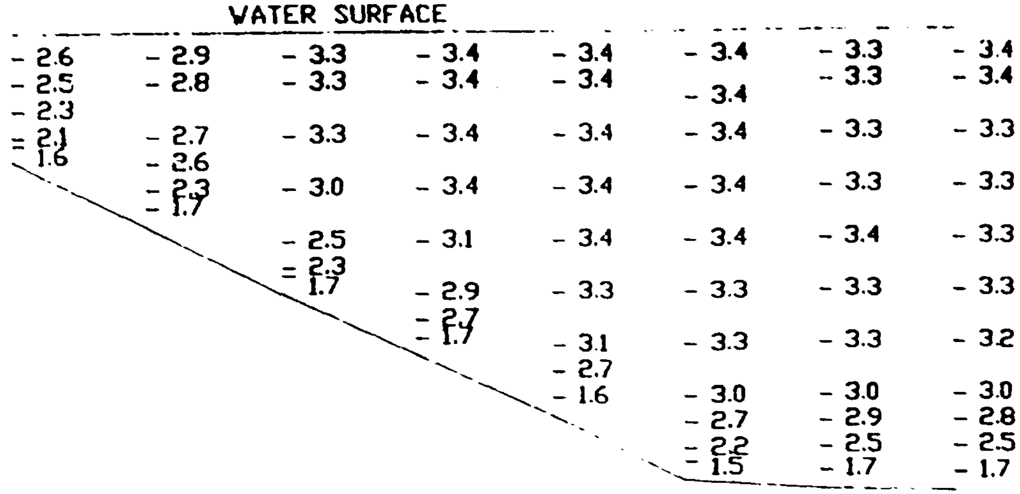
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.863

SIDE SLOPE VELOCITIES

TEST 7015S306.GR2

8.5	8	7.5	7	6.5	6	5.5	5	X, FT
0.48	0.73	0.99	1.22	1.46	1.71	1.75	1.76	DEPTH, FT
2.21	2.49	2.85	3.05	3.10	3.09	3.07	3.06	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

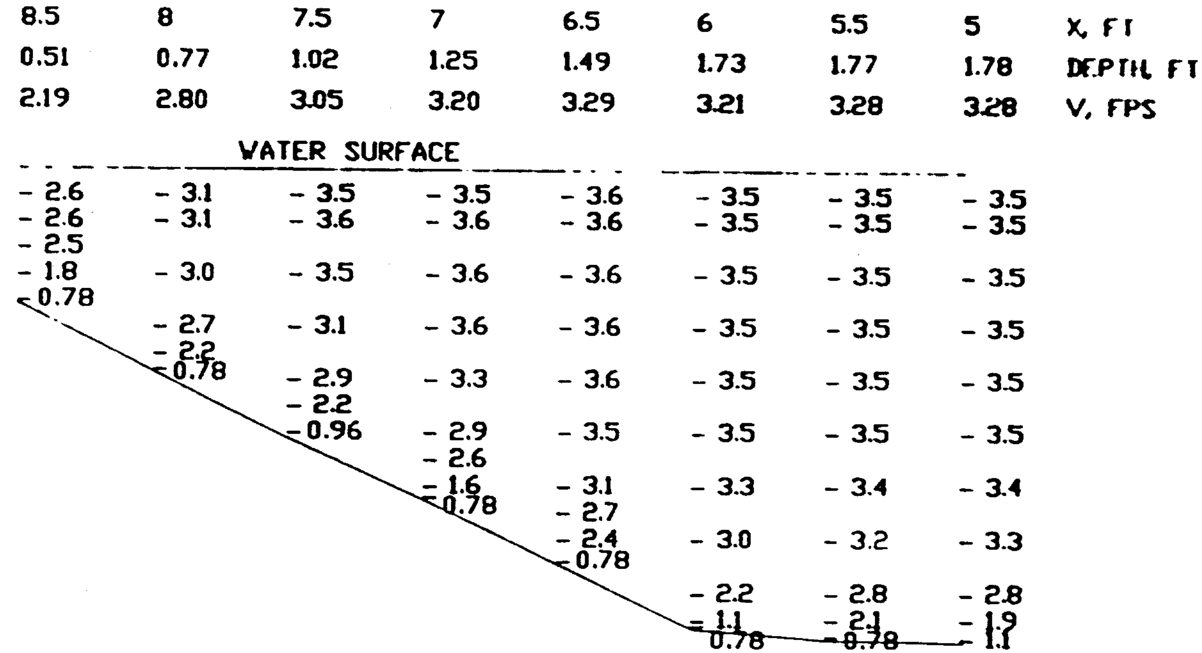
V = DEPTH-AVERAGED VELOCITY, FPS

3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.801

SIDE SLOPE VELOCITIES

TEST 60S281.GR3



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.876

SIDE SLOPE VELOCITIES

TEST 652S231.GR3

X, FT	8.5	8	7.5	7	6.5	6	5.5	5
DEPTH, FT	0.65	0.91	1.15	1.39	1.63	1.87	1.88	1.9
V, FPS	2.51	3.06	3.17	3.36	3.33	3.26	3.31	3.31

VATER SURFACE

8.5	8	7.5	7	6.5	6	5.5	5
- 3.0 - 2.9 - 2.7 - 2.4 - 1.8	- 3.6 - 3.6 - 3.4 - 3.1 - 2.9 - 2.6 - 1.8	- 3.6 - 3.6 - 3.6 - 3.5 - 3.3 - 3.0 - 2.8 - 1.7	- 3.7 - 3.7 - 3.7 - 3.7 - 3.7 - 3.5 - 3.2 - 2.6 - 1.4	- 3.7 - 3.7 - 3.6 - 3.7 - 3.6 - 3.5 - 3.4 - 3.2 - 2.9 - 1.5	- 3.6 - 3.5 - 3.5 - 3.6 - 3.6 - 3.6 - 3.5 - 3.5 - 2.9 - 2.7 - 1.9 - 1.3	- 3.6 - 3.6 - 3.6 - 3.6 - 3.6 - 3.6 - 3.5 - 3.5 - 3.1 - 2.9 - 2.0 - 1.5	- 3.6 - 3.5 - 3.6 - 3.6 - 3.5 - 3.6 - 3.6 - 3.5 - 3.3 - 3.0 - 2.1 - 1.5

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

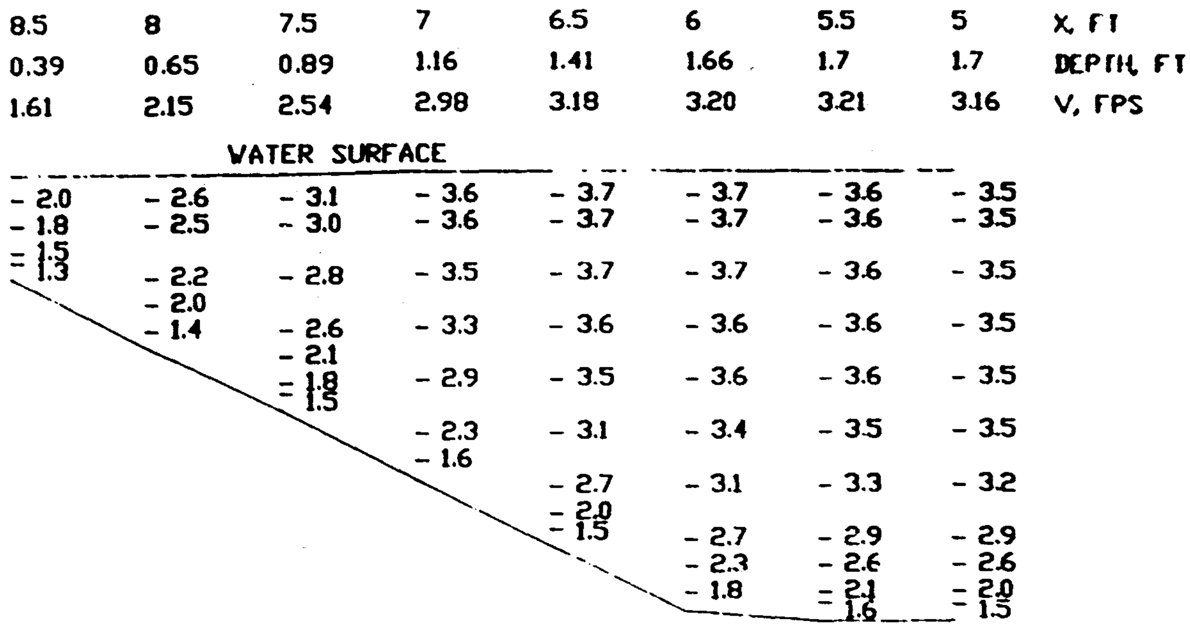
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.916

SIDE SLOPE VELOCITIES

TEST 70S281.GR3



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

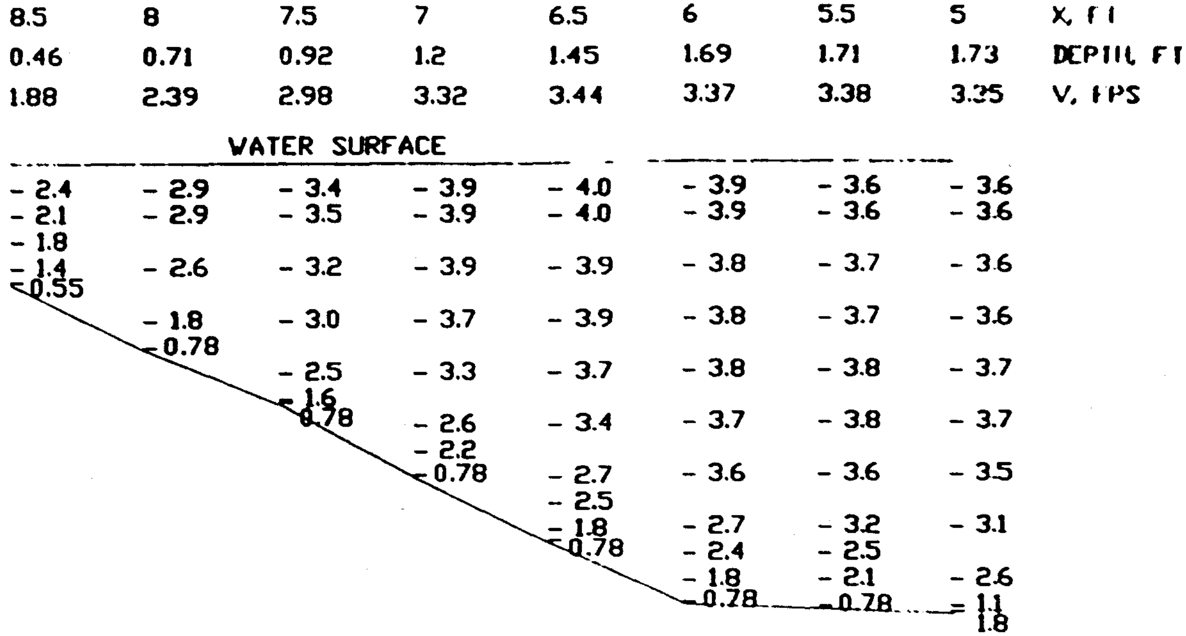
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.763

SIDE SLOPE VELOCITIES

TEST 60S306.GR3



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.848

SIDE SLOPE VELOCITIES

TEST 652S306.GR3

X, FT	8.5	8	7.5	7	6.5	6	5.5	5
DEPTH, FT	0.55	0.80	1.06	1.31	1.56	1.8	1.83	1.82
V, FPS	1.98	2.65	3.14	3.40	3.39	3.43	3.47	3.46

VATER SURFACE

- 2.5	- 3.3	- 3.8	- 3.9	- 3.9	- 3.9	- 3.8	- 3.7
- 2.3	- 3.2	- 3.8	- 3.9	- 3.9	- 3.9	- 3.8	- 3.7
- 2.1	- 2.9	- 3.6	- 3.9	- 3.8	- 3.8	- 3.7	- 3.7
- 1.7	- 2.5	- 3.4	- 3.8	- 3.8	- 3.8	- 3.8	- 3.7
- 1.4	- 2.0	- 2.9	- 3.7	- 3.7	- 3.7	- 3.8	- 3.7
	- 1.3	- 2.5	- 3.1	- 3.6	- 3.7	- 3.8	- 3.8
		- 1.7	- 2.9	- 3.3	- 3.6	- 3.7	- 3.8
			- 2.4	- 3.0	- 3.3	- 3.4	- 3.5
			- 1.6	- 2.5	- 2.7	- 3.0	- 2.9
				- 1.4	- 2.2	- 2.5	- 2.5
					- 1.4	- 1.7	- 1.9

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

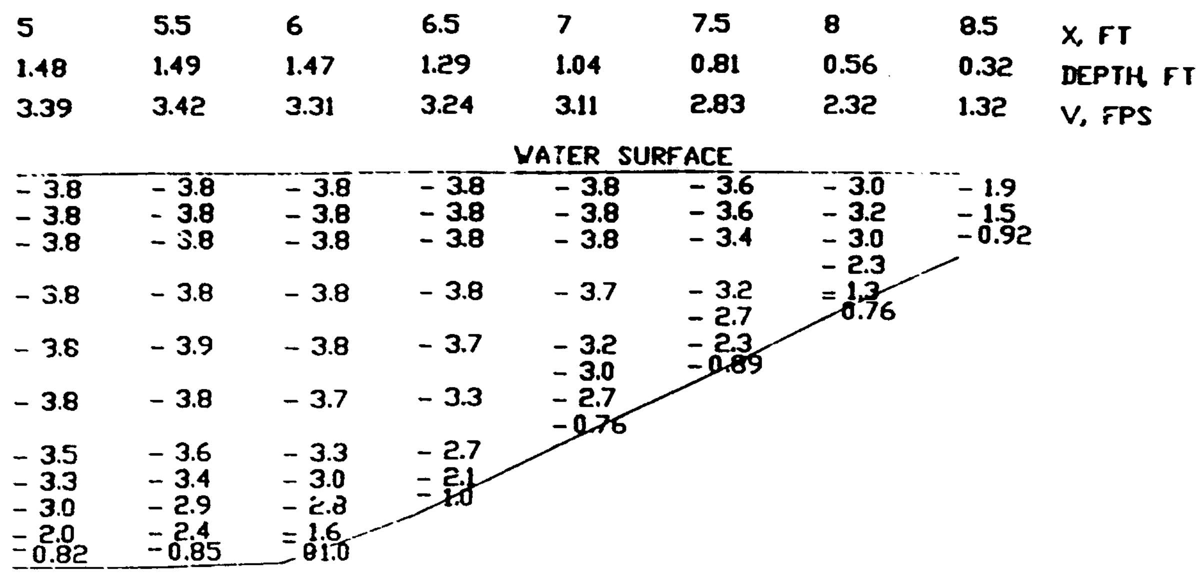
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.898

SIDE SLOPE VELOCITIES

TEST 70S306.GR3



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

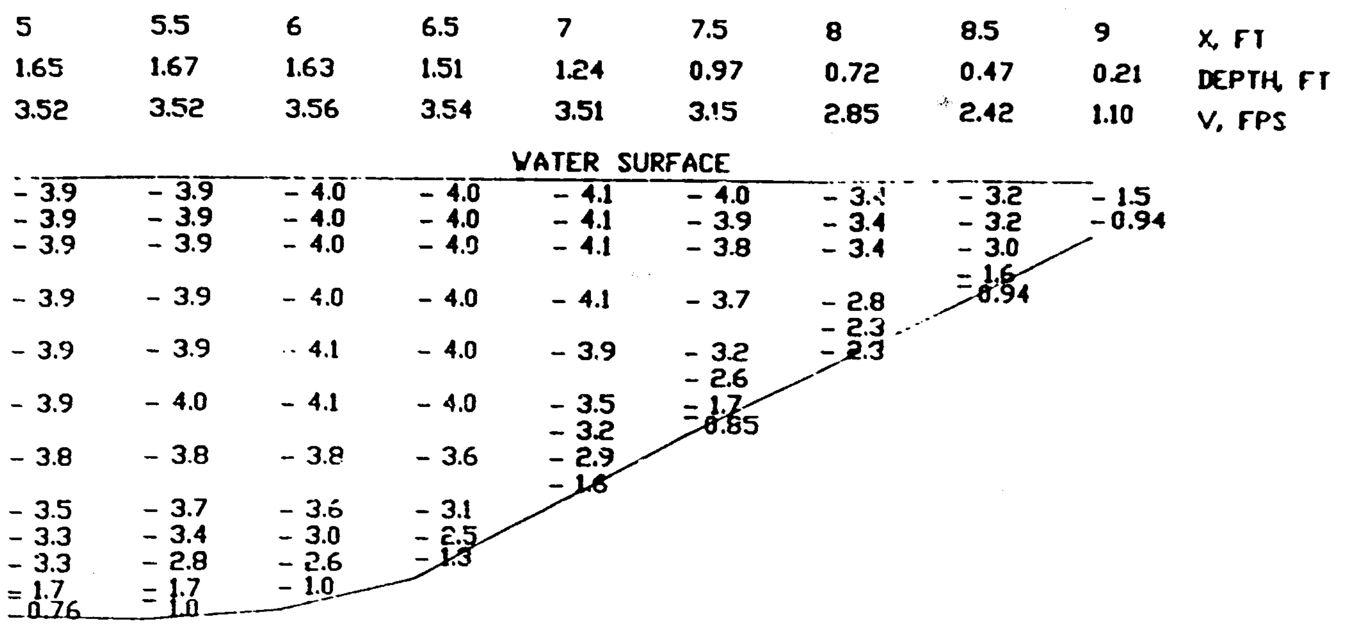
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.913

SIDE SLOPE VELOCITIES

TEST 502S578.GR3



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

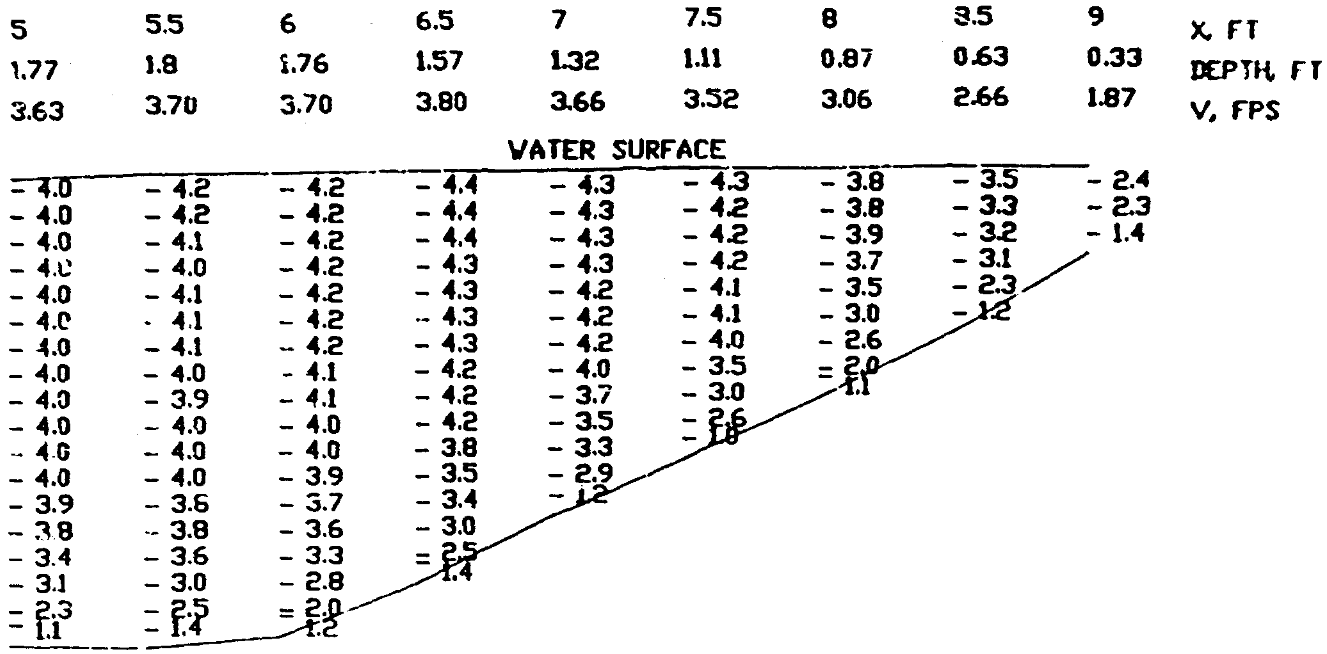
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.073

SIDE SLOPE VELOCITIES

TEST 602S578.GR3

PLATE A40



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

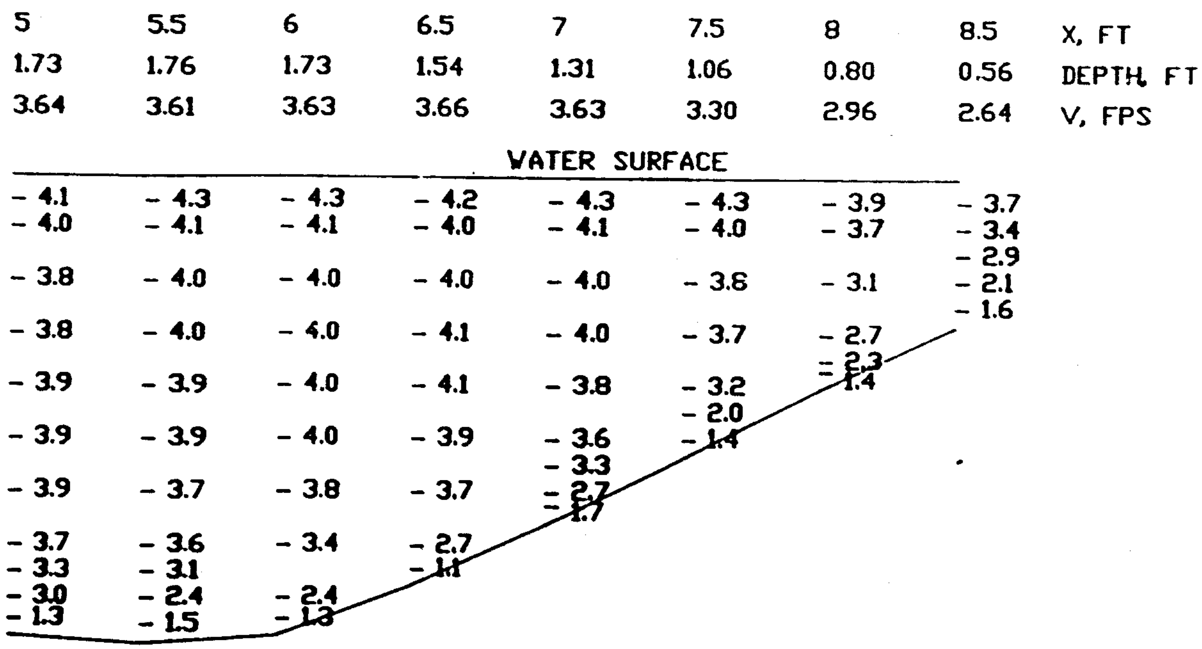
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.223

SIDE SLOPE VELOCITIES

TEST 702S578.GR3



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

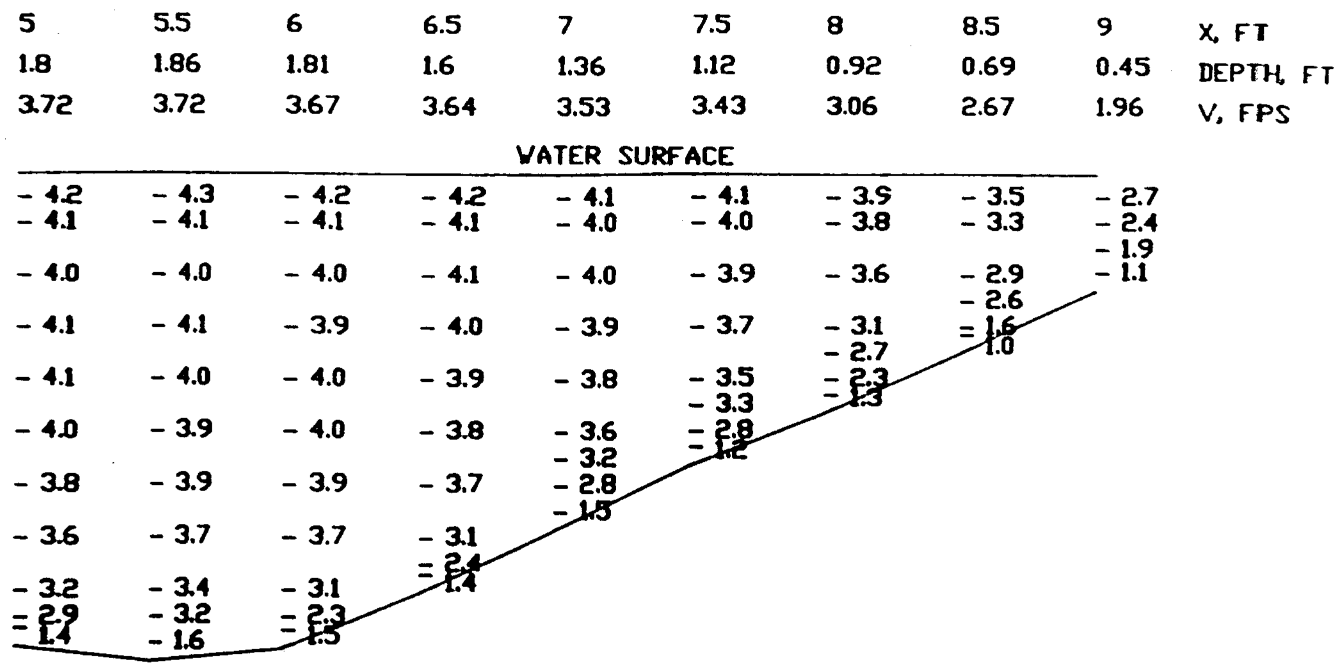
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.273

SIDE SLOPE VELOCITIES

TEST 702S578.GR4



LÉGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

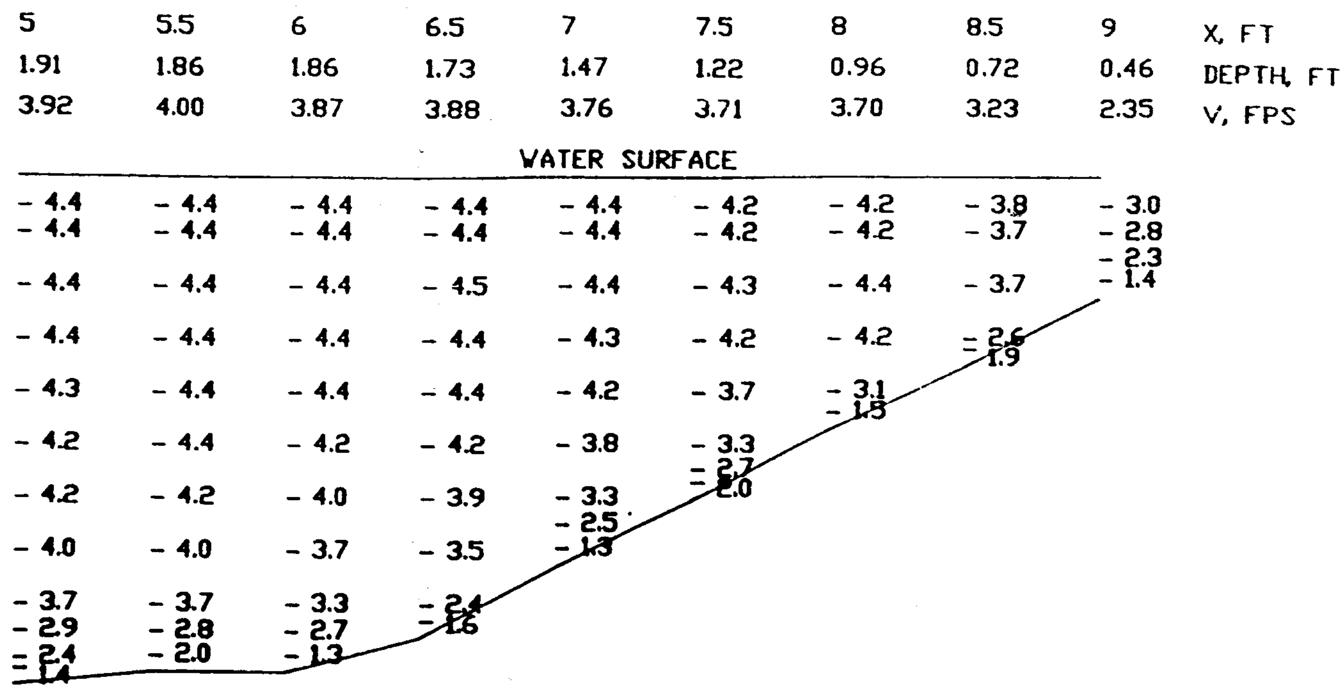
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.343

SIDE SLOPE VELOCITIES

TEST 752S578.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

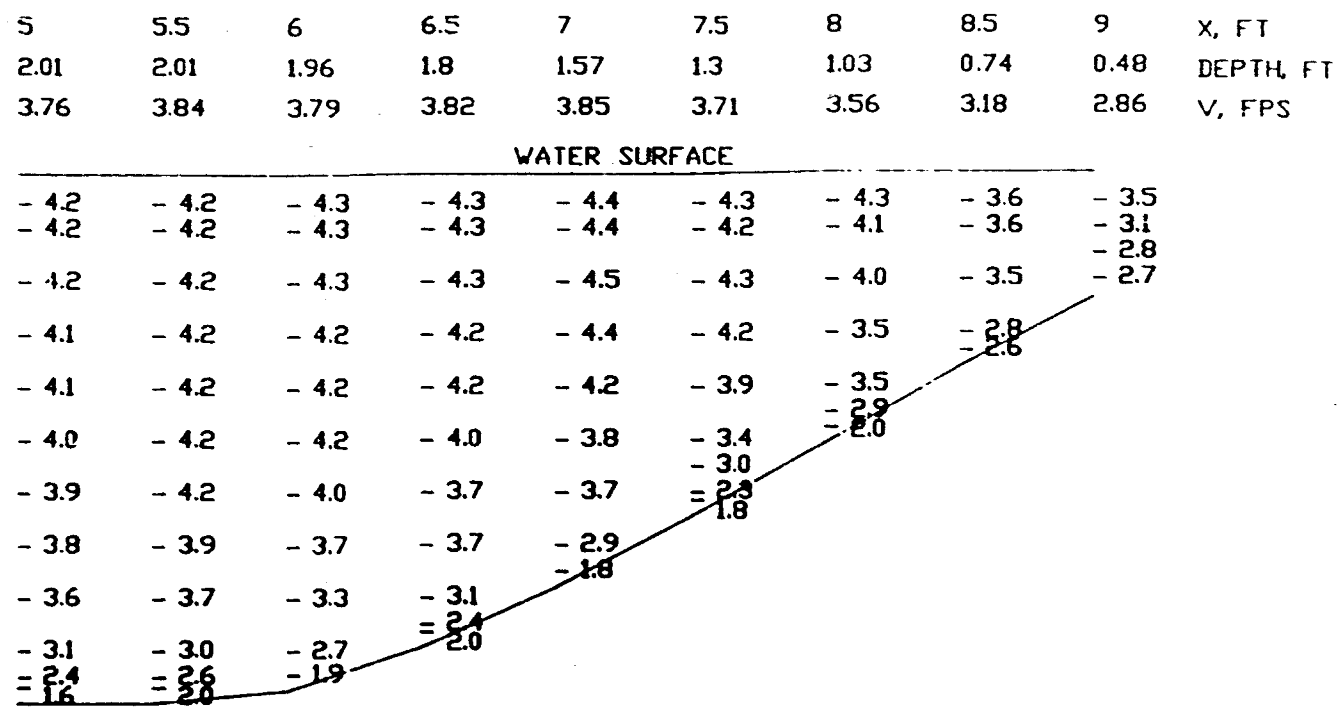
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.383

SIDE SLOPE VELOCITIES

TEST 802S578.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

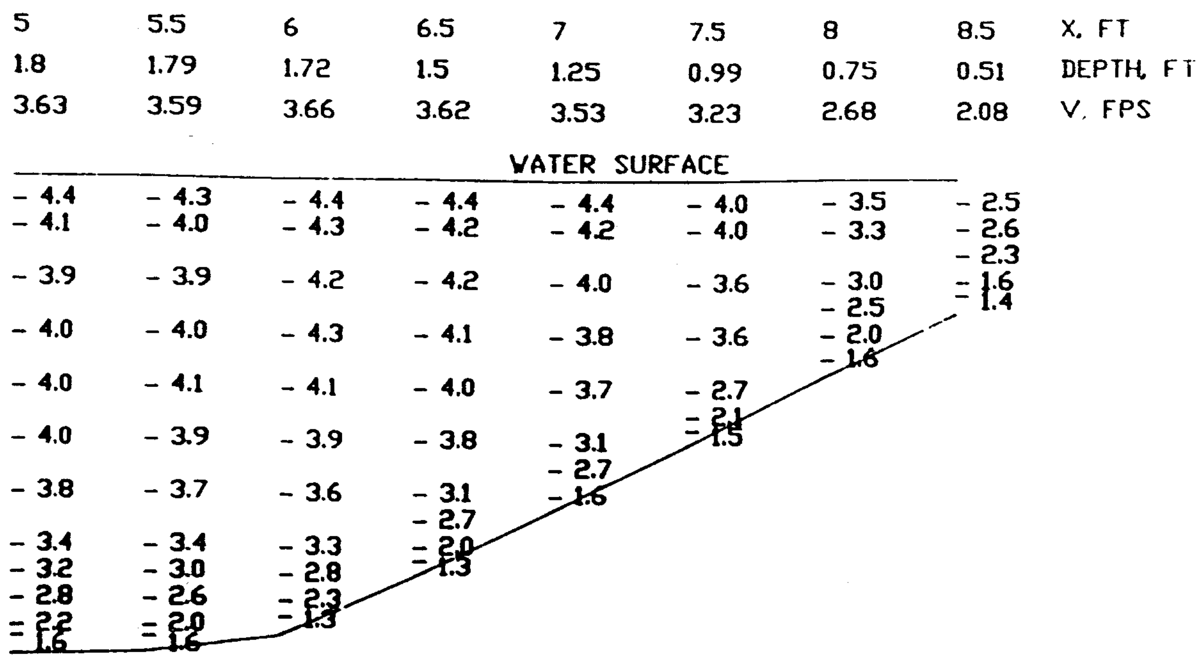
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.523

SIDE SLOPE VELOCITIES

TEST 902S578.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

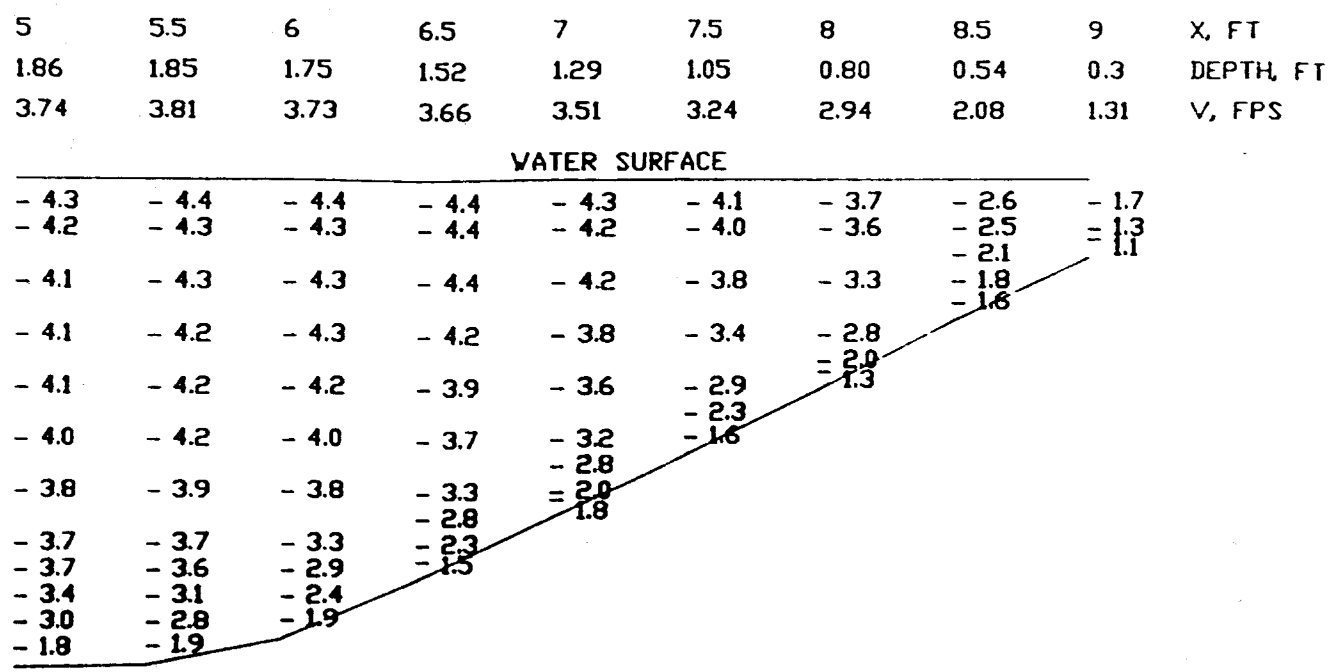
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.233

SIDE SLOPE VELOCITIES

TEST 702S602.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

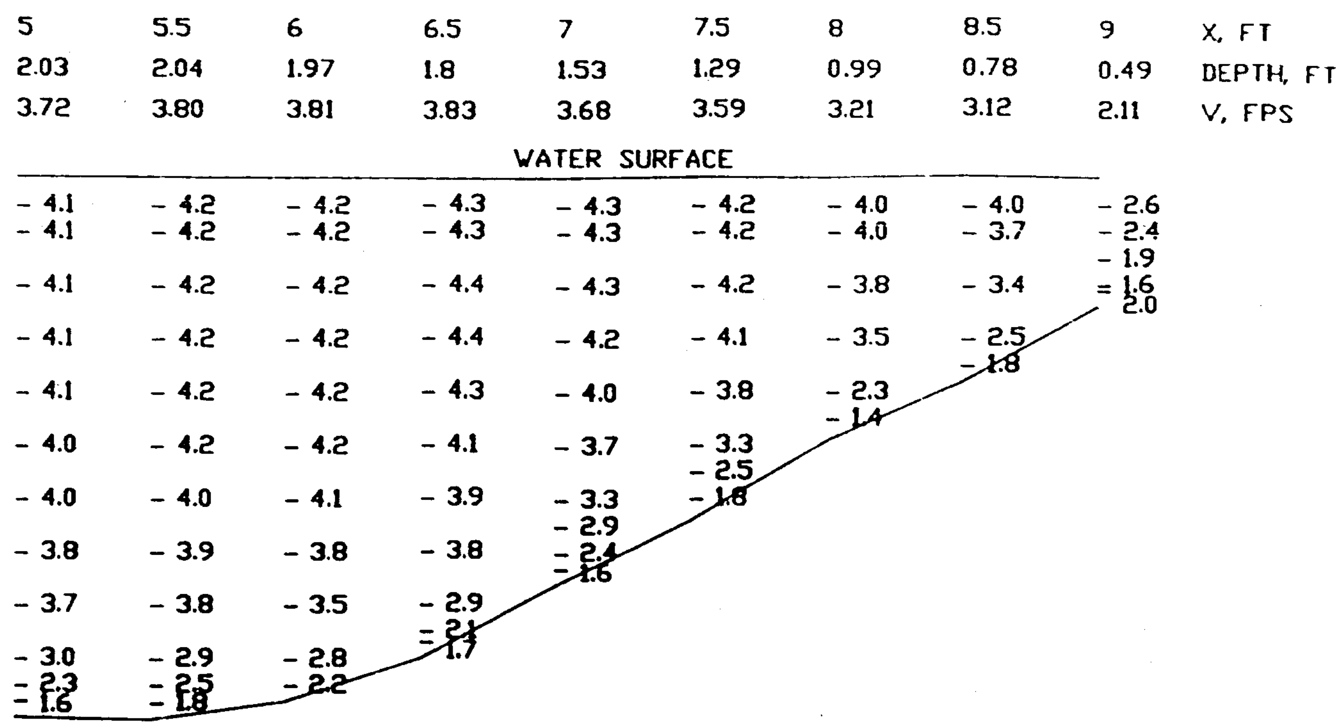
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.303

SIDE SLOPE VELOCITIES

TEST 752S602.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

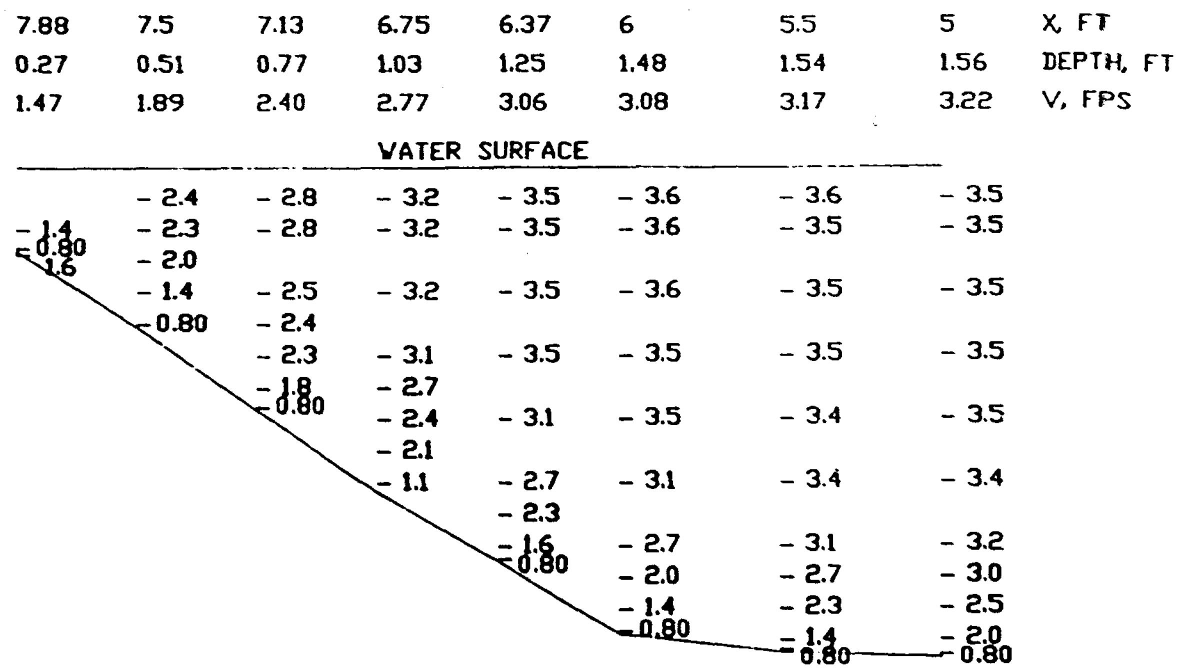
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.473

SIDE SLOPE VELOCITIES

TEST 902S602.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

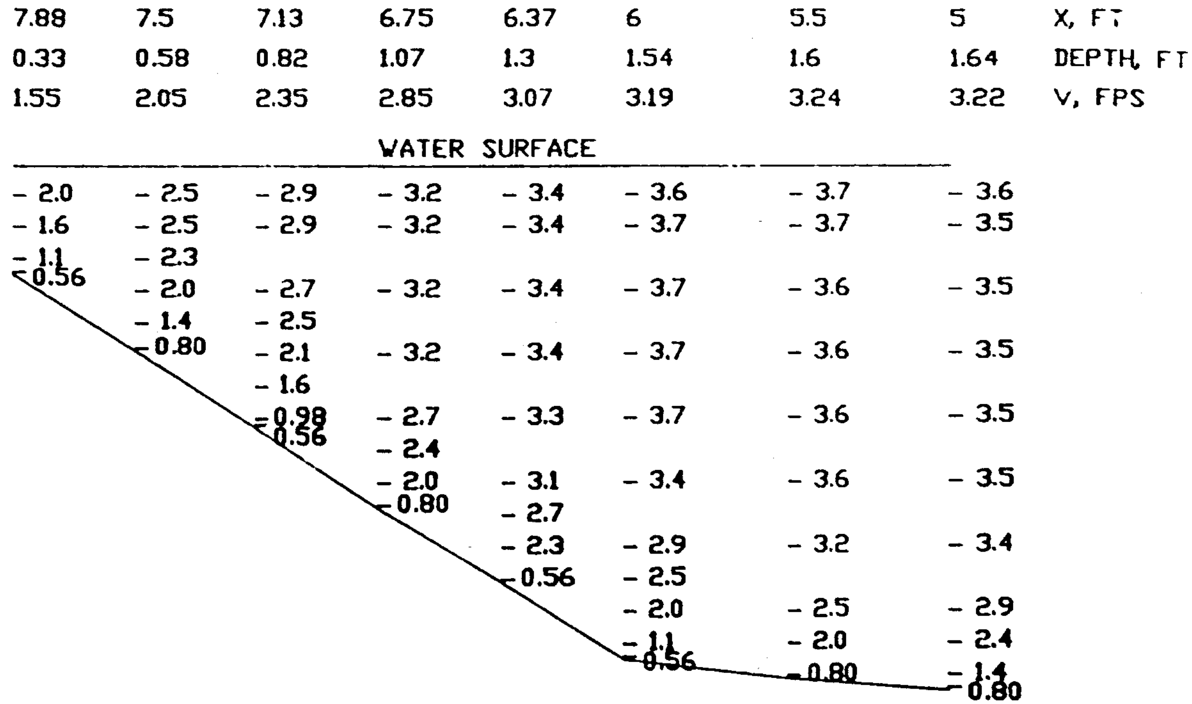
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: VATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.646

SIDE SLOPE VELOCITIES

TEST 5015S201.GR4



<u>LEGEND</u>

X = DISTANCE FROM CHANNEL CENTER LINE, FT

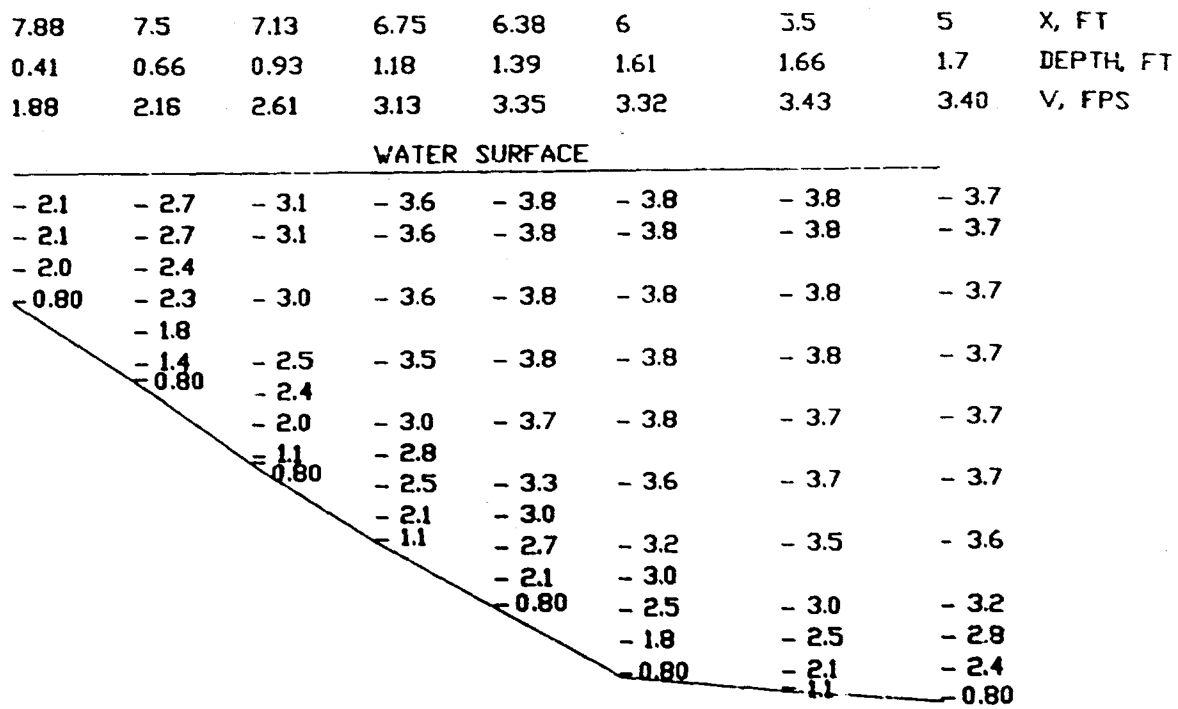
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.676

SIDE SLOPE VELOCITIES

TEST 5515S281.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

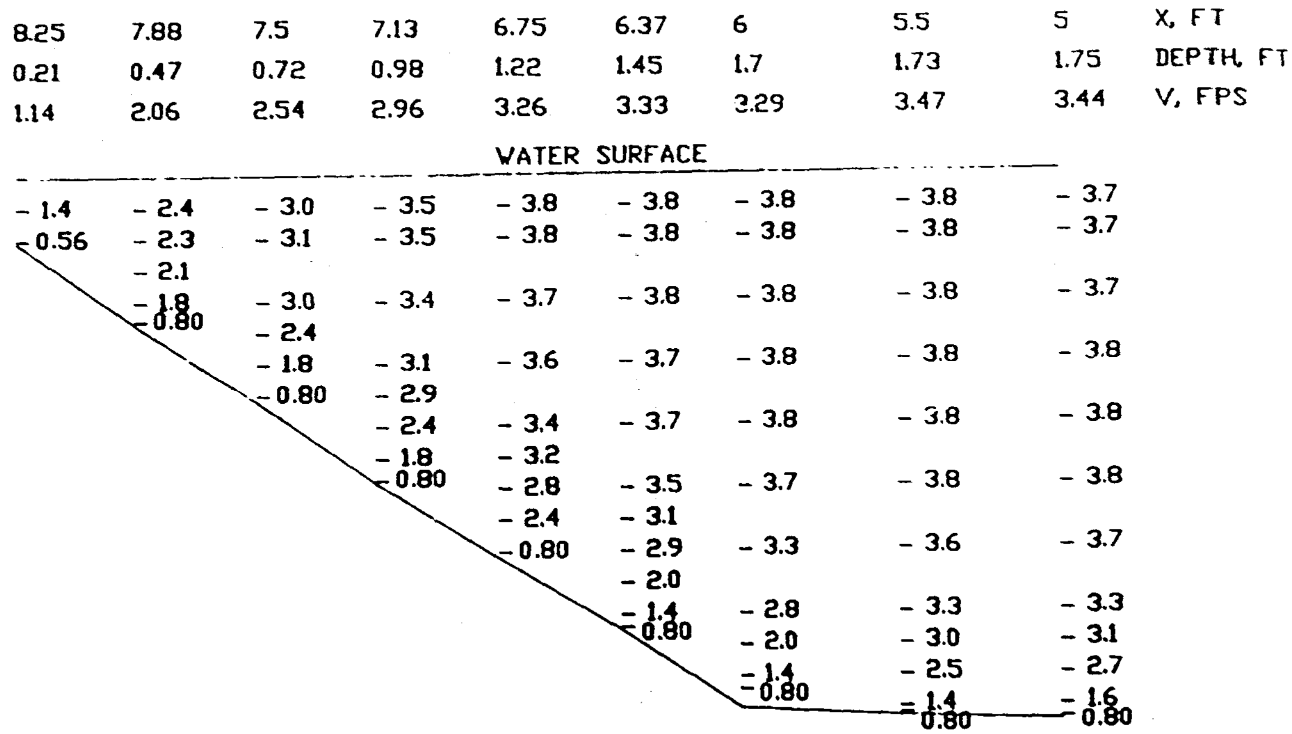
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.736

SIDE SLOPE VELOCITIES

TEST 6015S281.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

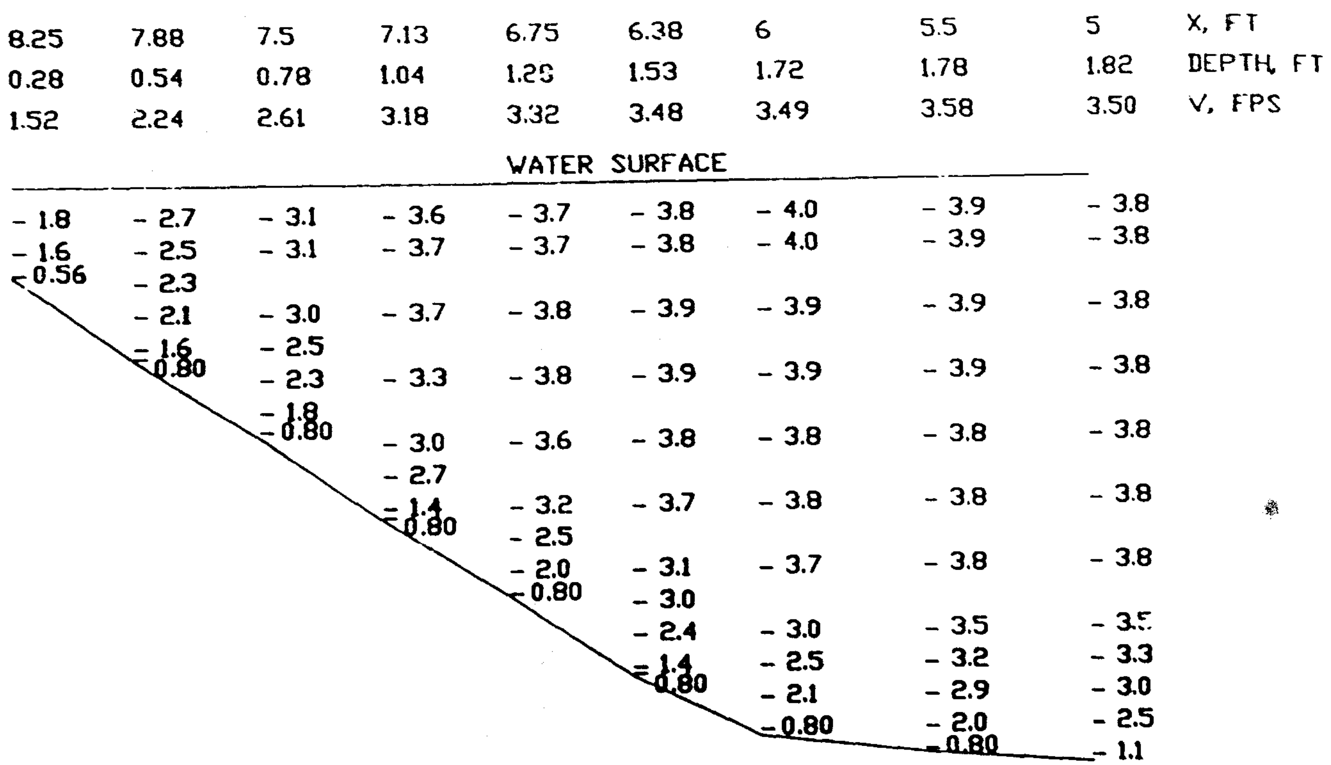
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.816

SIDE SLOPE VELOCITIES

TEST 6515S281.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

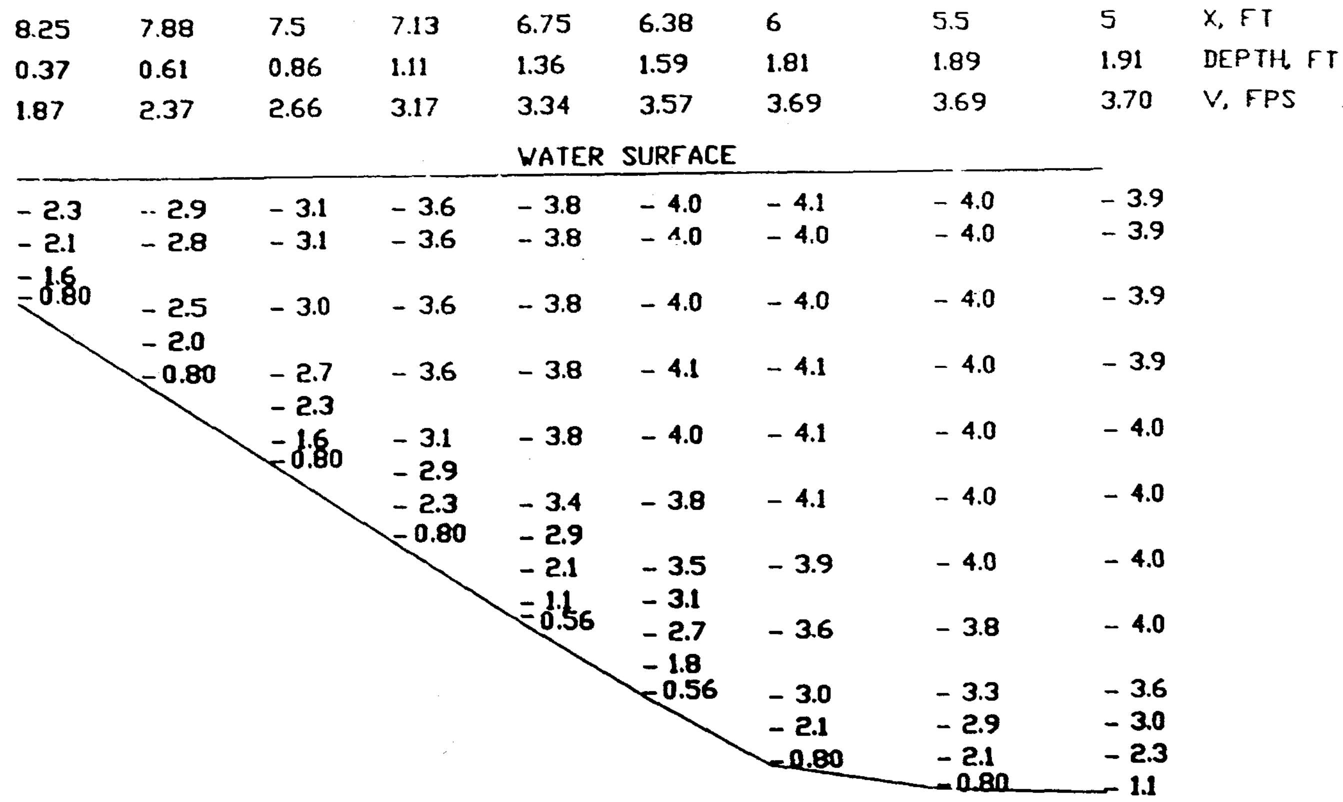
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.886

SIDE SLOPE VELOCITIES

TEST 7015S281.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

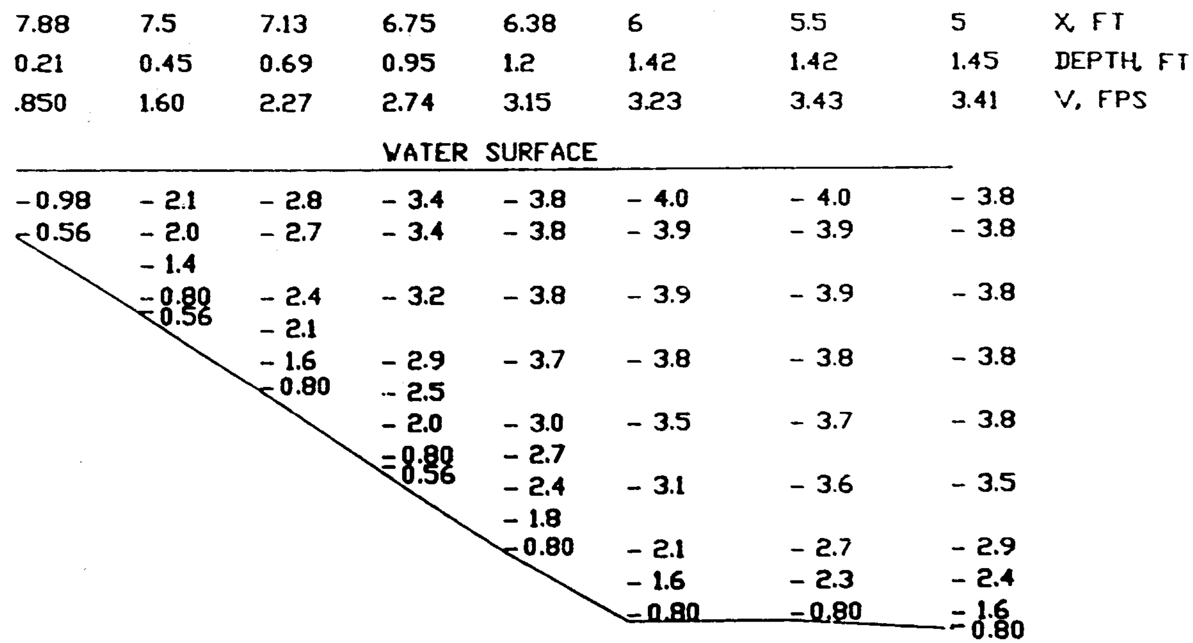
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.956

SIDE SLOPE VELOCITIES

TEST 7515S281.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

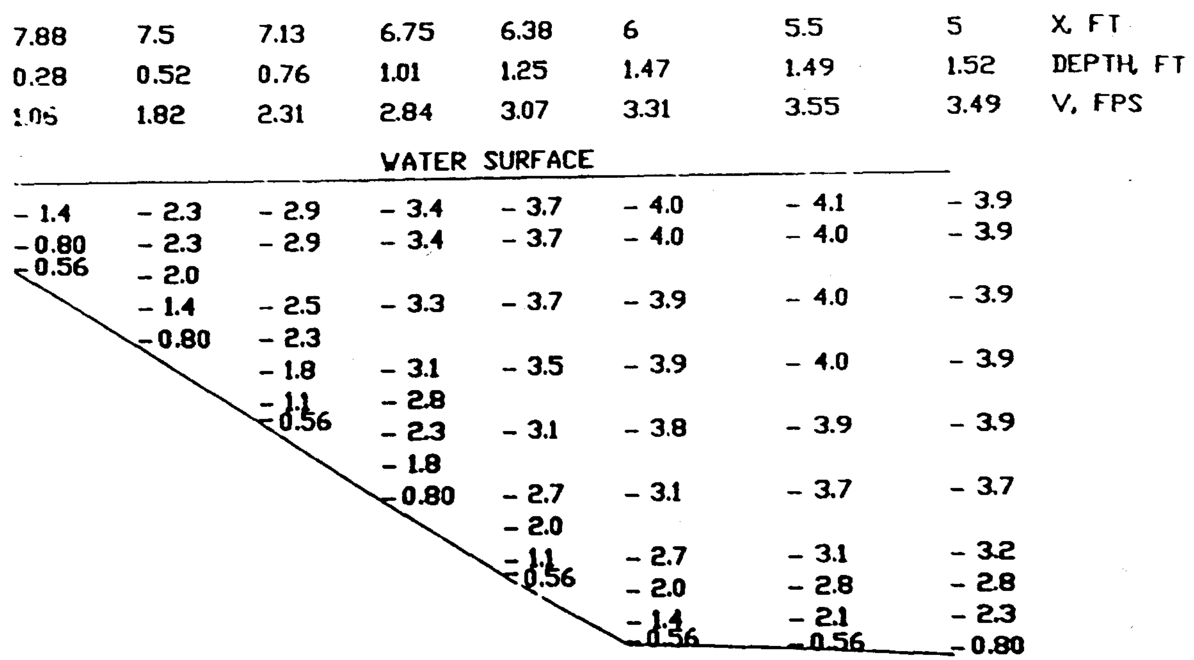
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.603

SIDE SLOPE VELOCITIES

TEST 5015S306.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

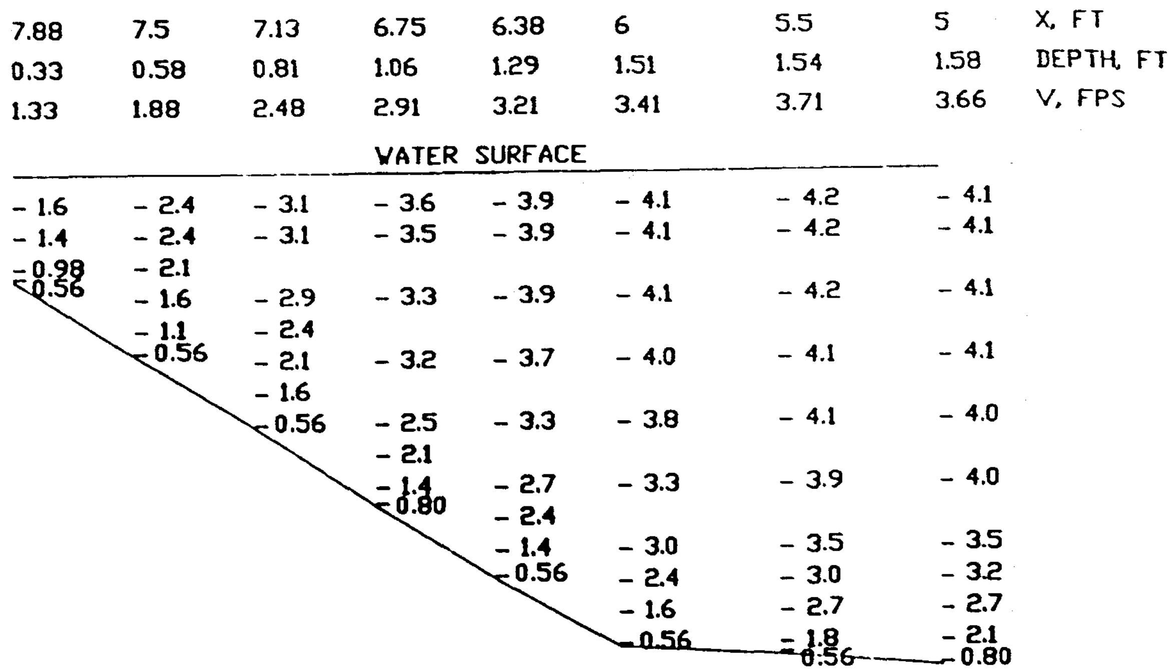
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.633

SIDE SLOPE VELOCITIES

TEST 5515S306.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

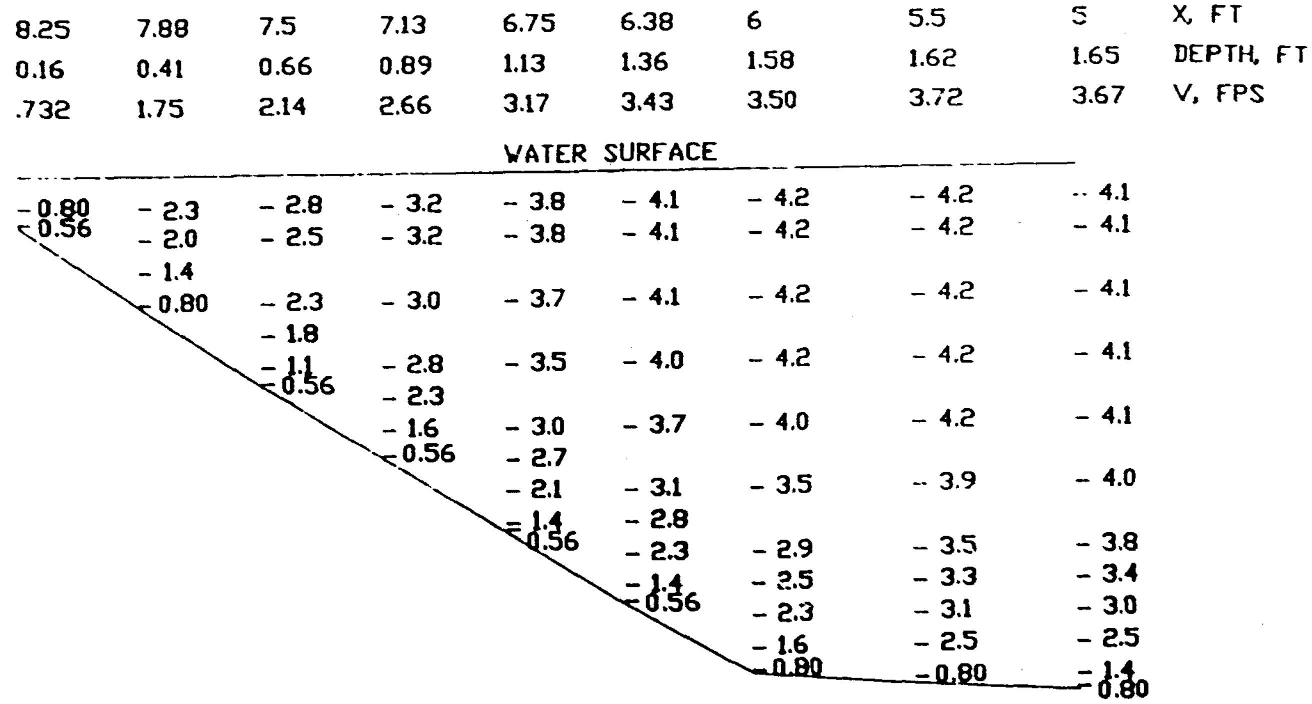
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: VATER-SIRFACE ELEVATION AT CHANNEL CENTER LINE = 180.693

SIDE SLOPE VELOCITIES

TEST 6015S306.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

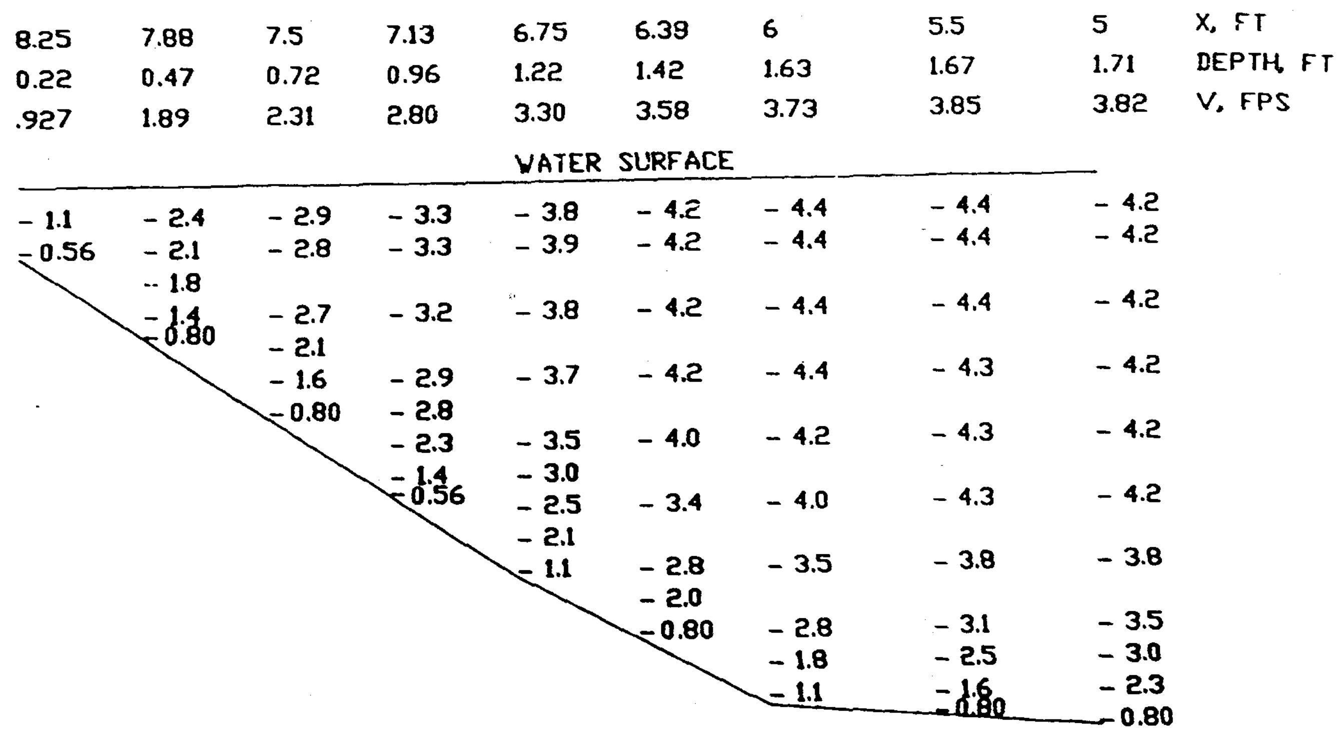
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.773

SIDE SLOPE VELOCITIES

TEST 6515S306.GR4



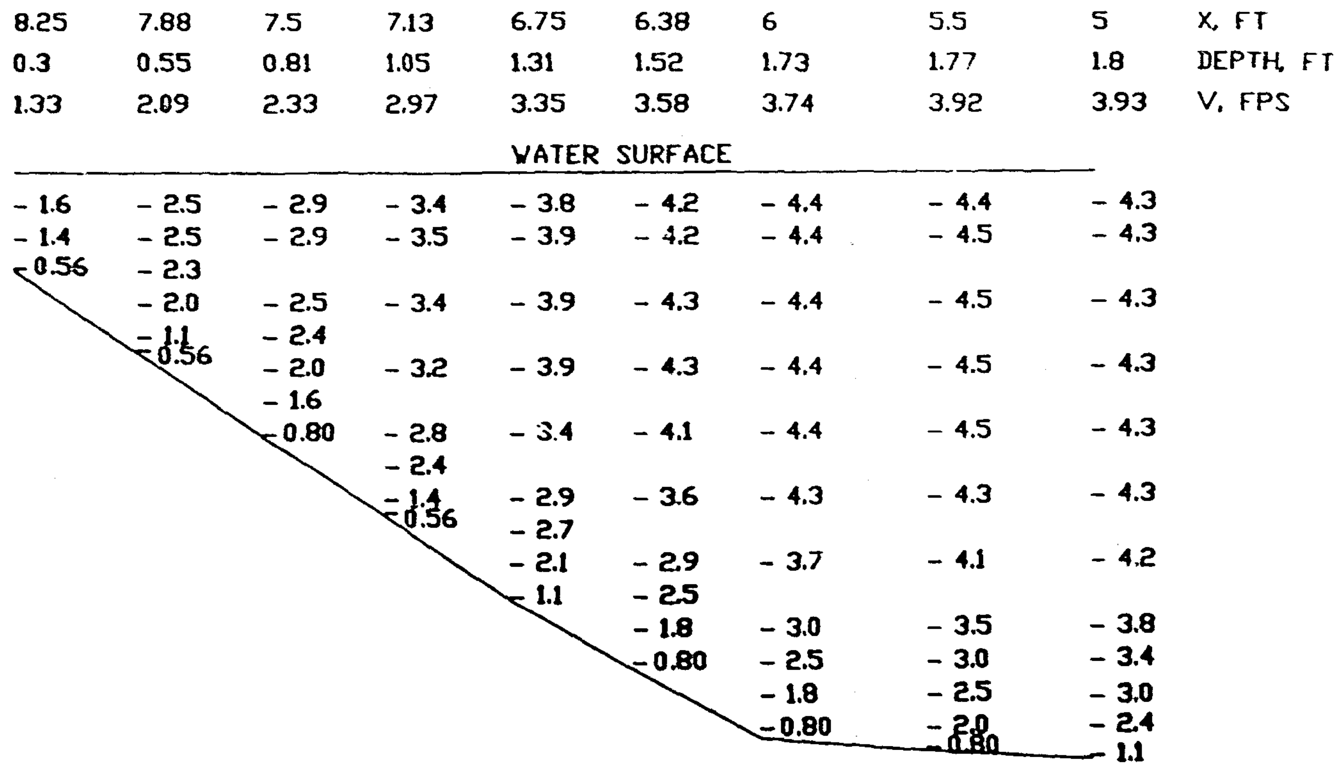
LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT
V = DEPTH-AVERAGED VELOCITY, FPS
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.84

SIDE SLOPE VELOCITIES

TEST 7015S306.GR4



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

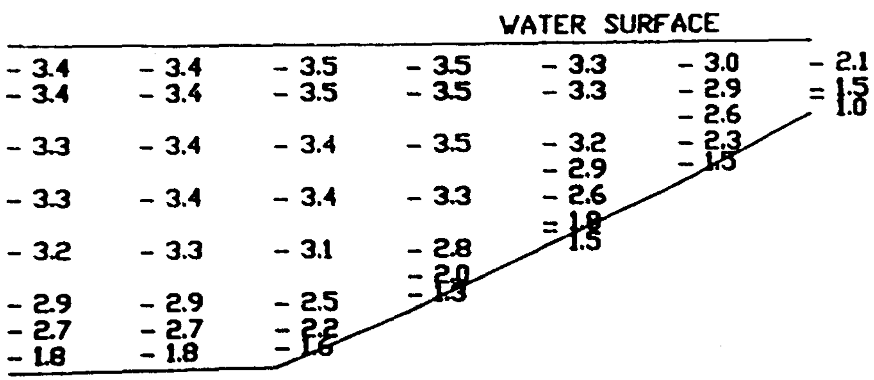
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.913

SIDE SLOPE VELOCITIES

TEST 7515S306.GR4

5	5.5	6	6.5	7	7.5	8	X, FT
1.25	1.24	1.23	1.02	0.77	0.53	0.27	DEPTH, FT
3.03	3.08	2.97	2.98	2.78	2.41	1.59	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

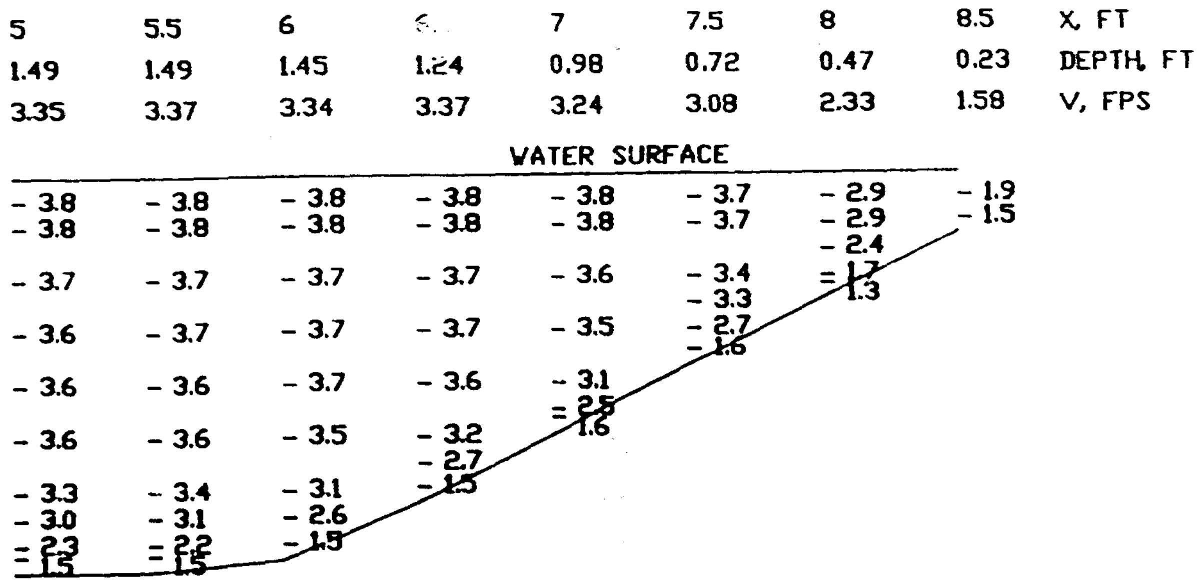
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.773

SIDE SLOPE VELOCITIES

TEST 402S578.GR5



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

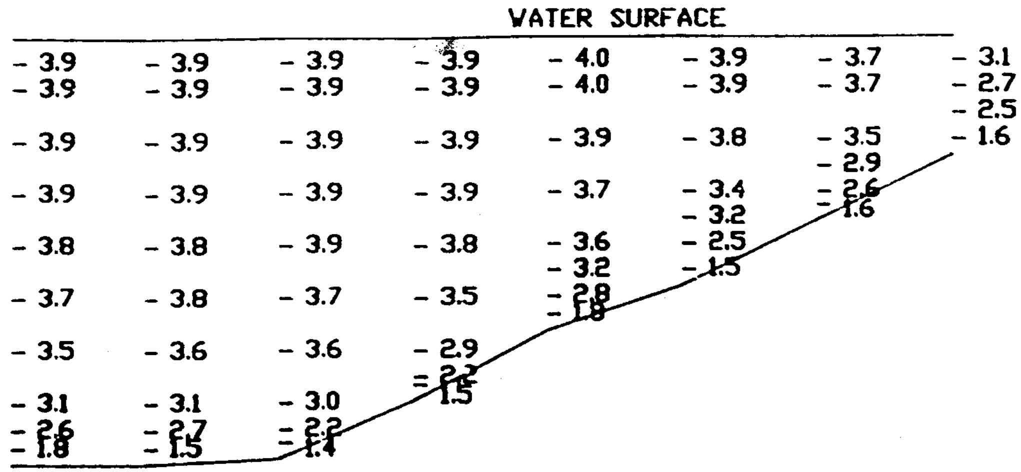
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.033

SIDE SLOPE VELOCITIES

TEST 502S578.GR5

5	5.5	6	6.5	7	7.5	8	8.5	X, FT
1.62	1.62	1.6	1.38	1.12	0.95	0.7	0.45	DEPTH, FT
3.48	3.49	3.53	3.49	3.49	3.25	3.10	2.43	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

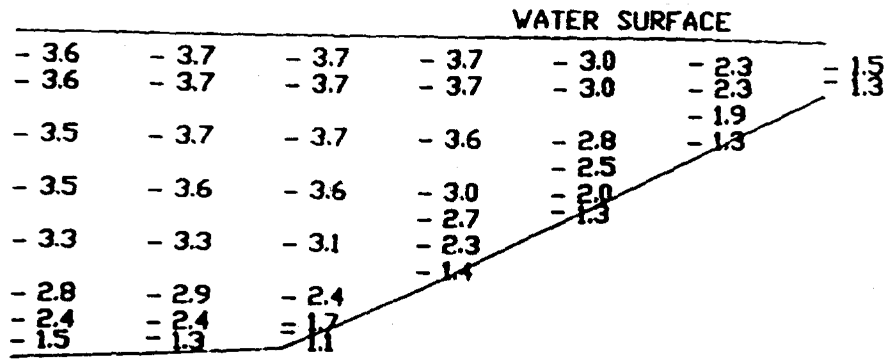
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.133

SIDE SLOPE VELOCITIES

TEST 602S578.GR5

5	5.5	6	6.5	7	7.5	8	X, FT
1.23	1.21	1.18	0.95	0.70	0.45	0.19	DEPTH, FT
3.11	3.20	3.13	2.97	2.52	1.88	1.24	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

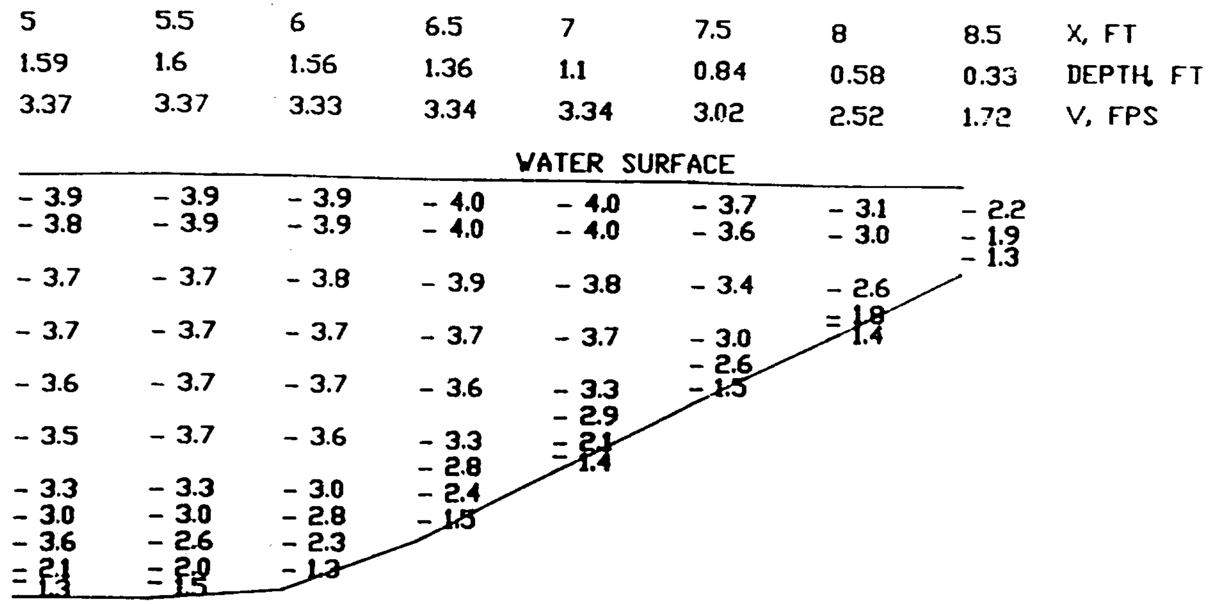
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.743

SIDE SLOPE VELOCITIES

TEST 402S602.GR5



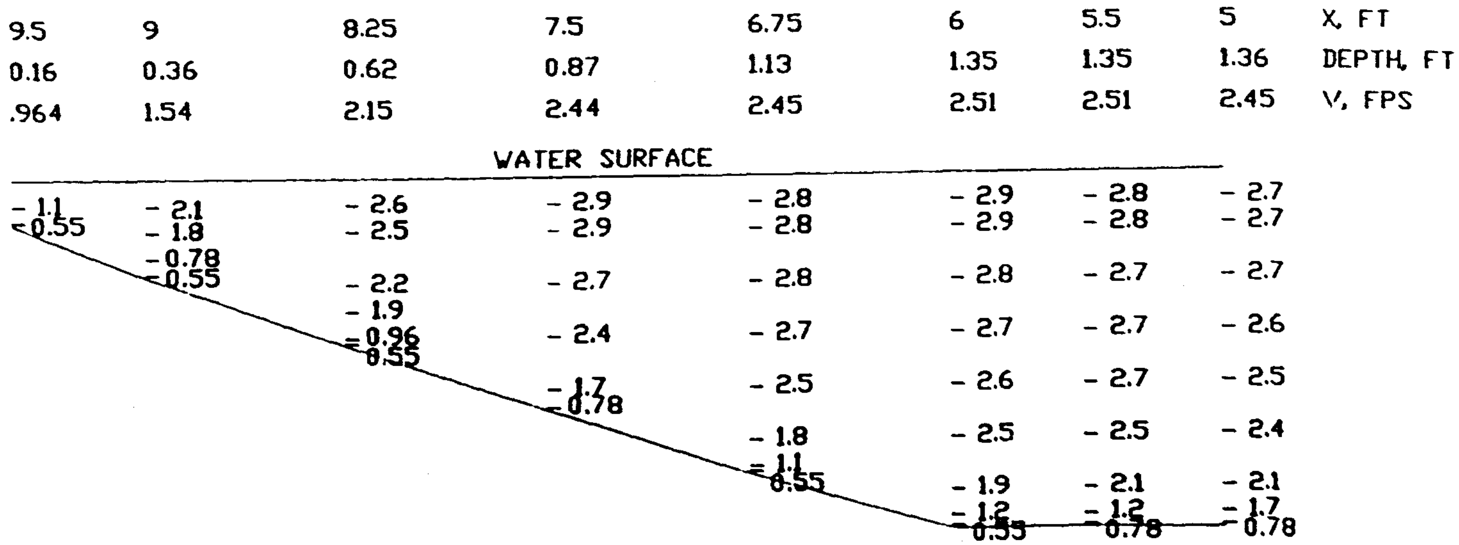
LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT
V = DEPTH-AVERAGED VELOCITY, FPS
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.073

SIDE SLOPE VELOCITIES

TEST 602S602.GR5



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

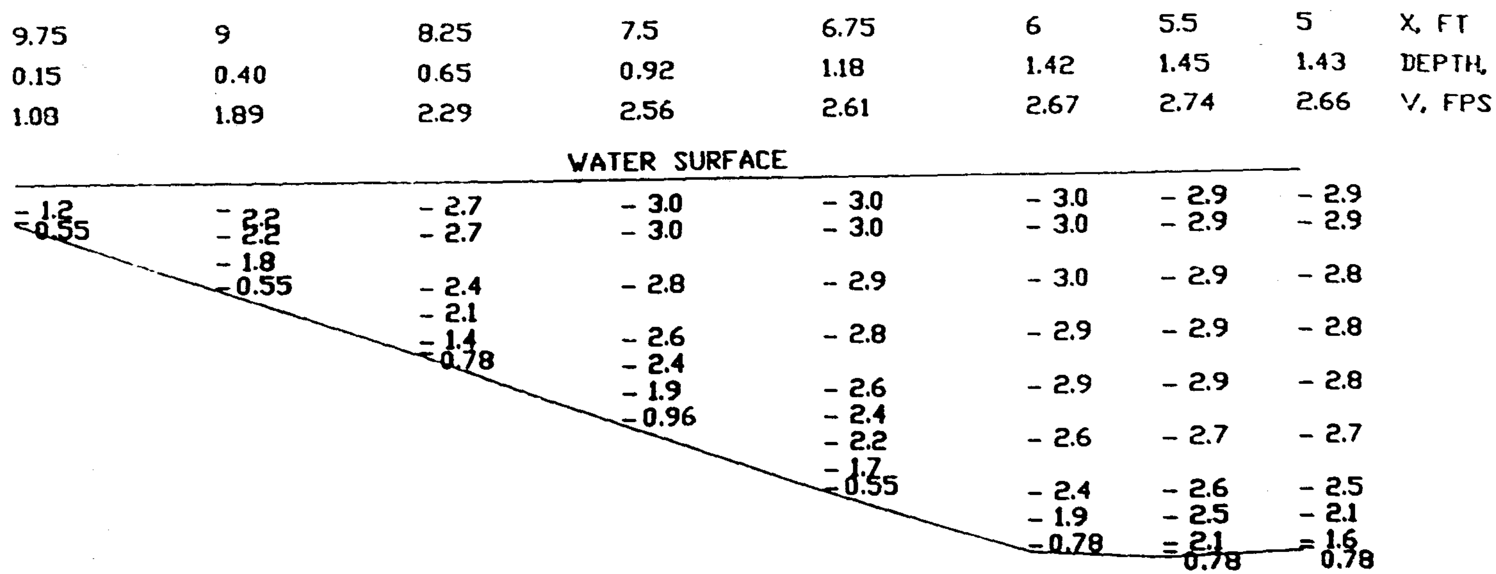
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.356

SIDE SLOPE VELOCITIES

TEST 403S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

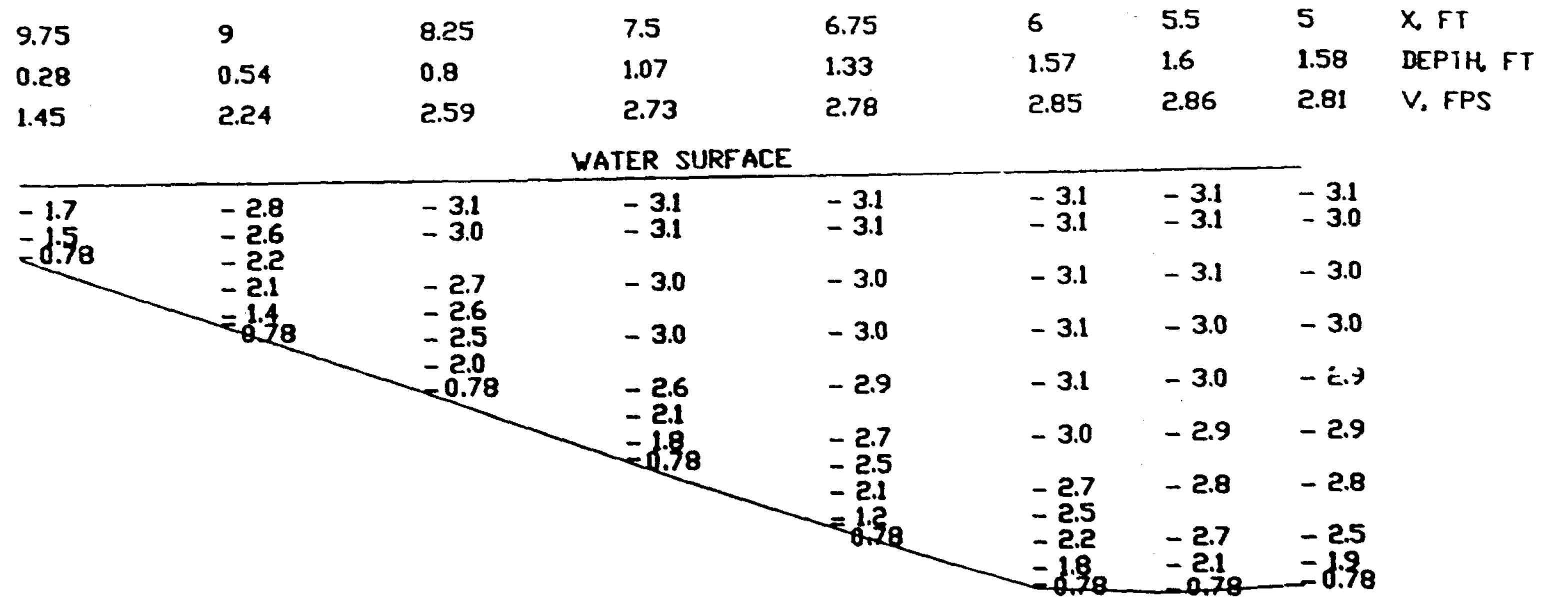
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.496

SIDE SLOPE VELOCITIES

TEST 453S281.GR6



<u>LEGEND</u>

X = DISTANCE FROM CHANNEL CENTER LINE, FT

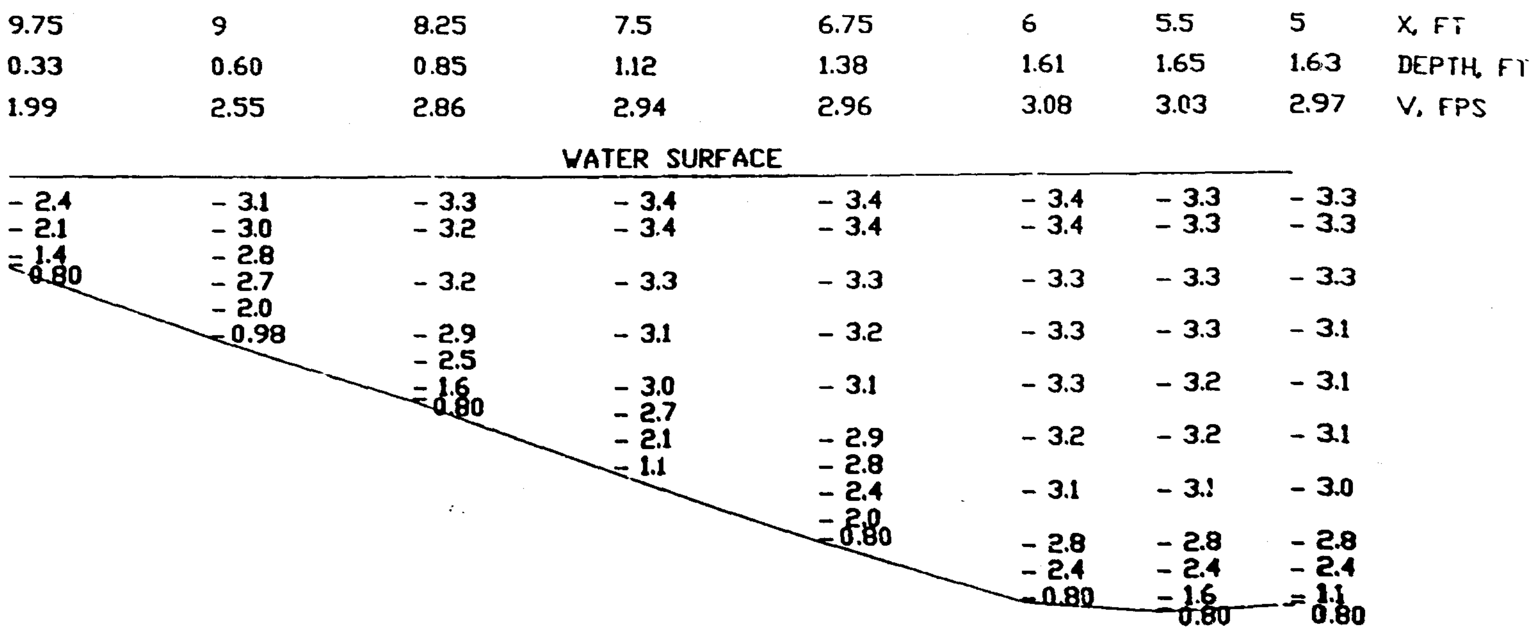
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.586

SIDE SLOPE VELOCITIES

TEST 503S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

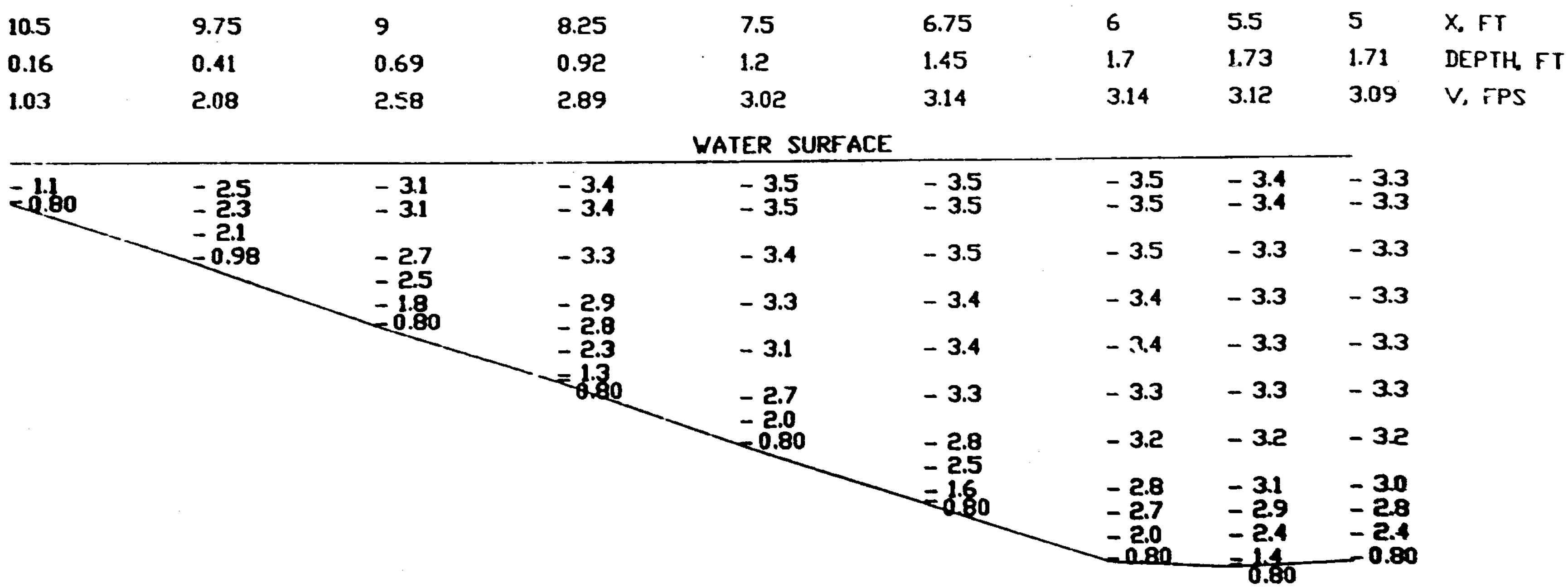
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.631

SIDE SLOPE VELOCITIES

TEST 553S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

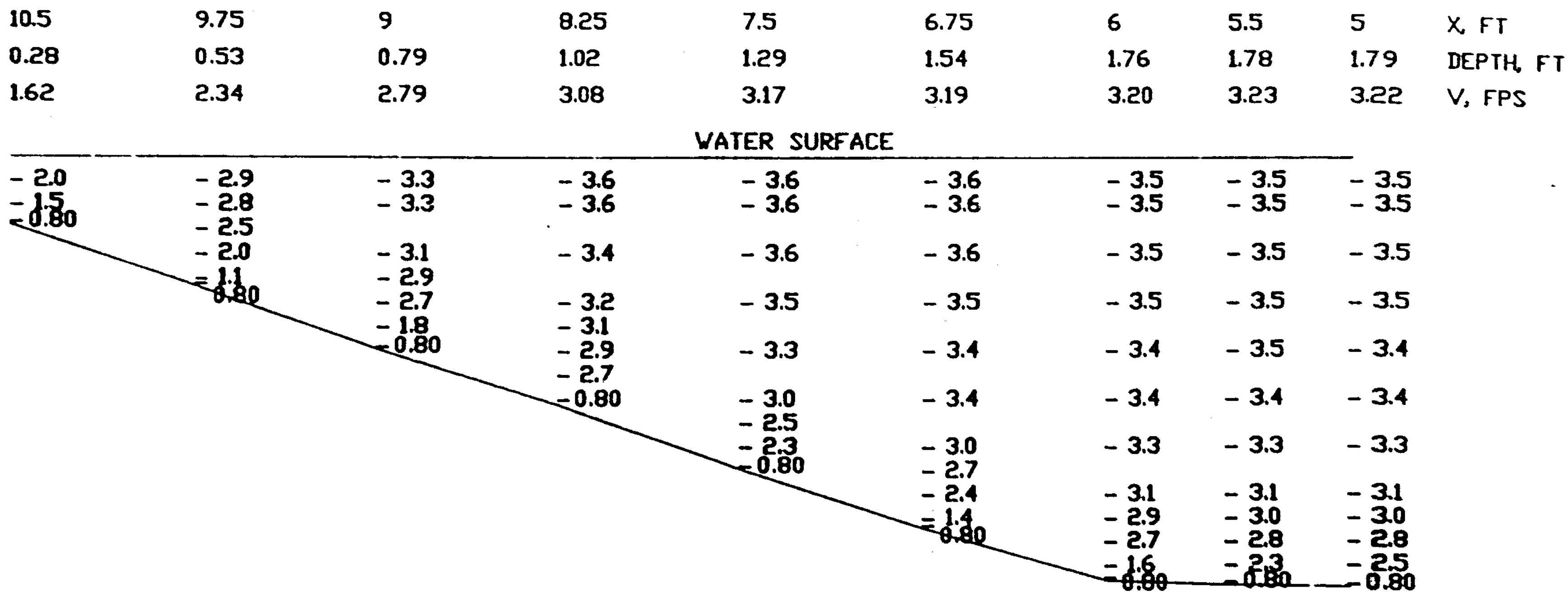
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.696

SIDE SLOPE VELOCITIES

TEST 603S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

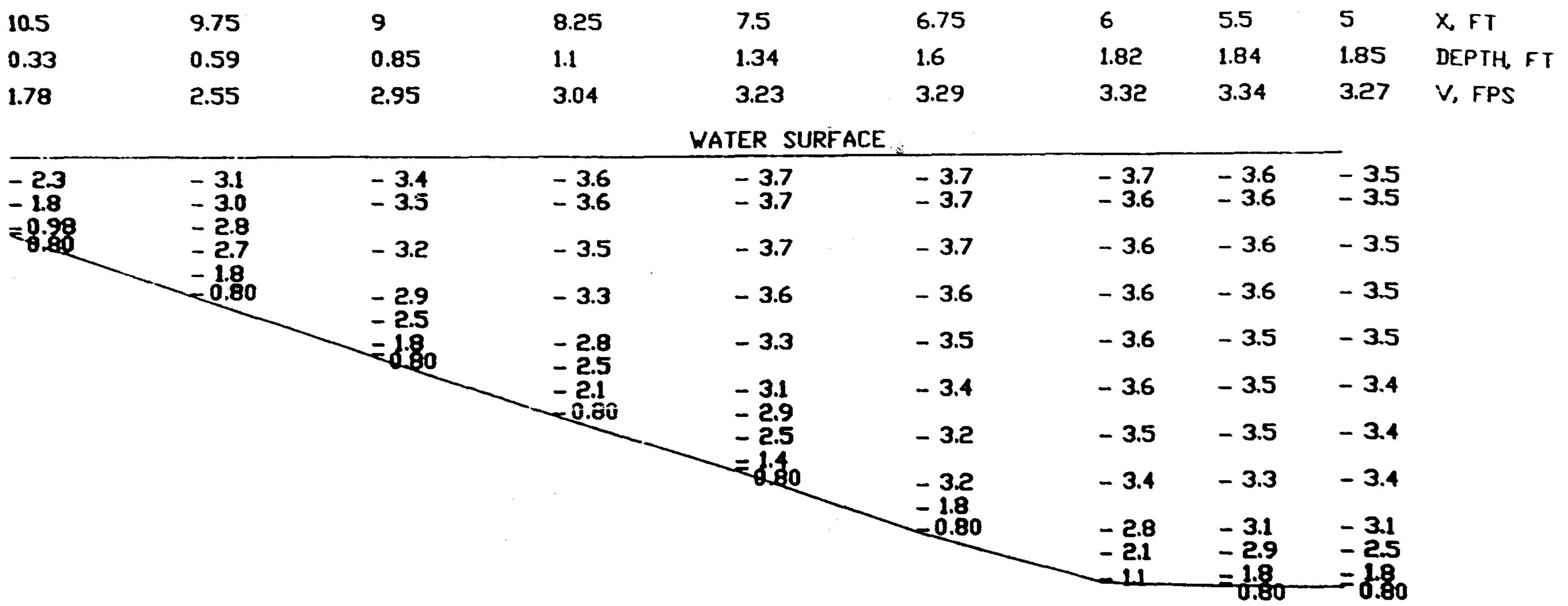
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.791

SIDE SLOPE VELOCITIES

TEST 653S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

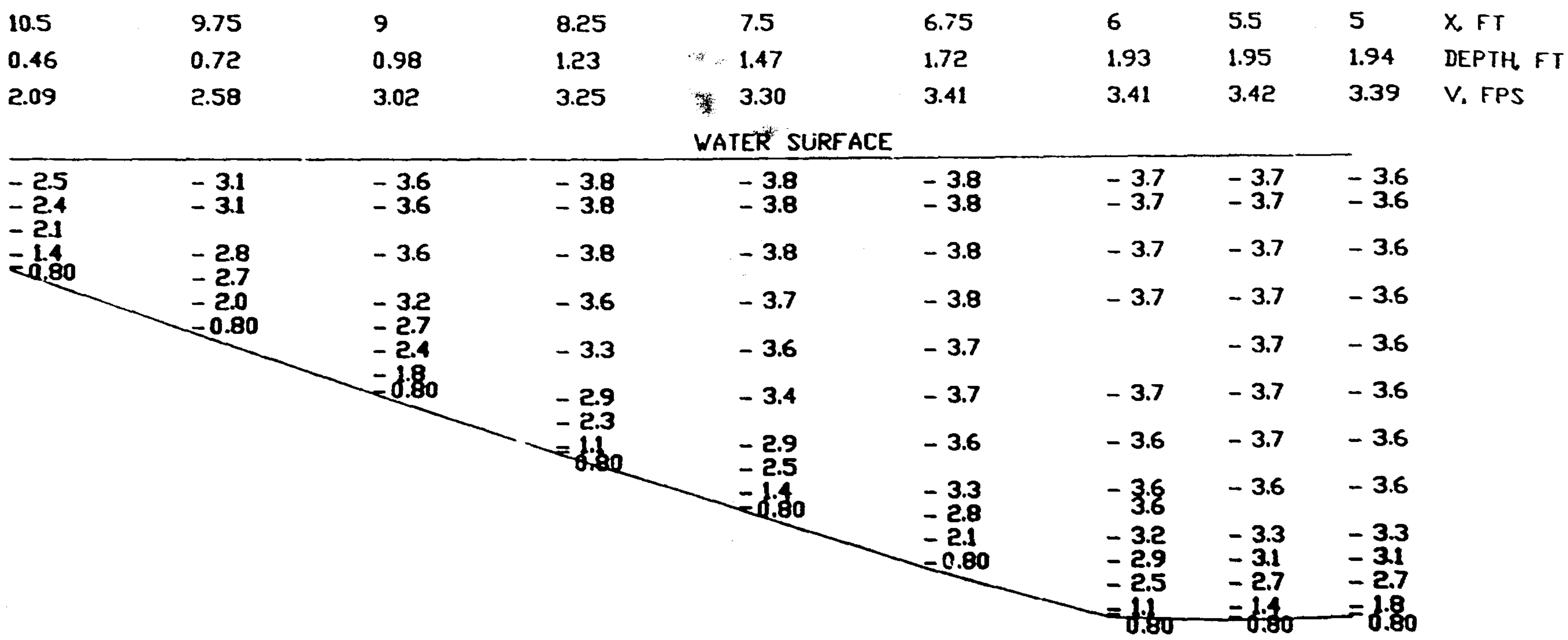
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.806

SIDE SLOPE VELOCITIES

TEST 703S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

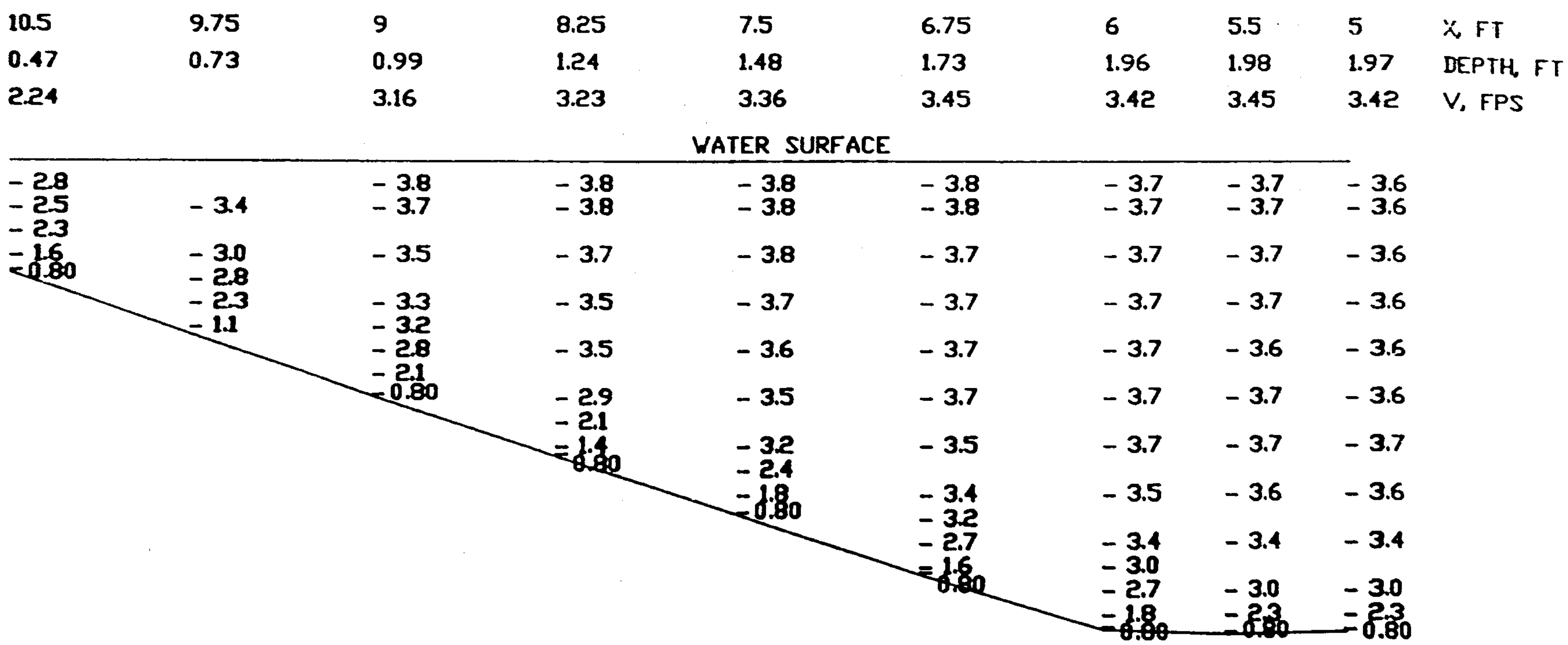
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.936

SIDE SLOPE VELOCITIES

TEST 753S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

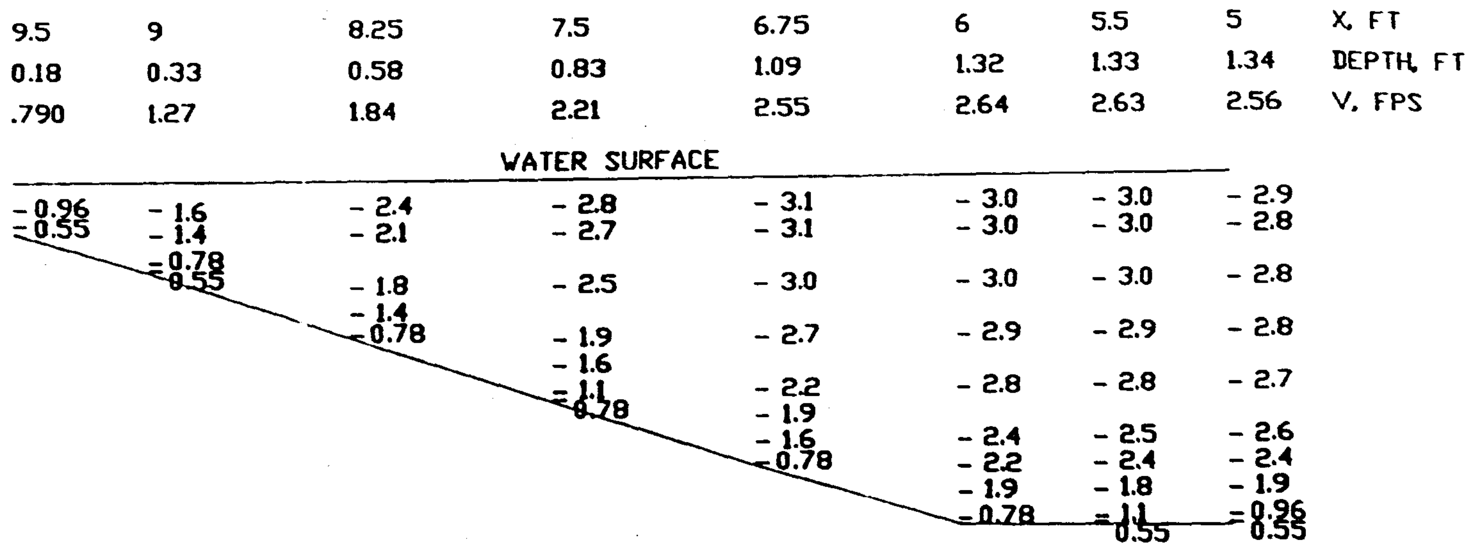
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.981

SIDE SLOPE VELOCITIES

TEST 803S281.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

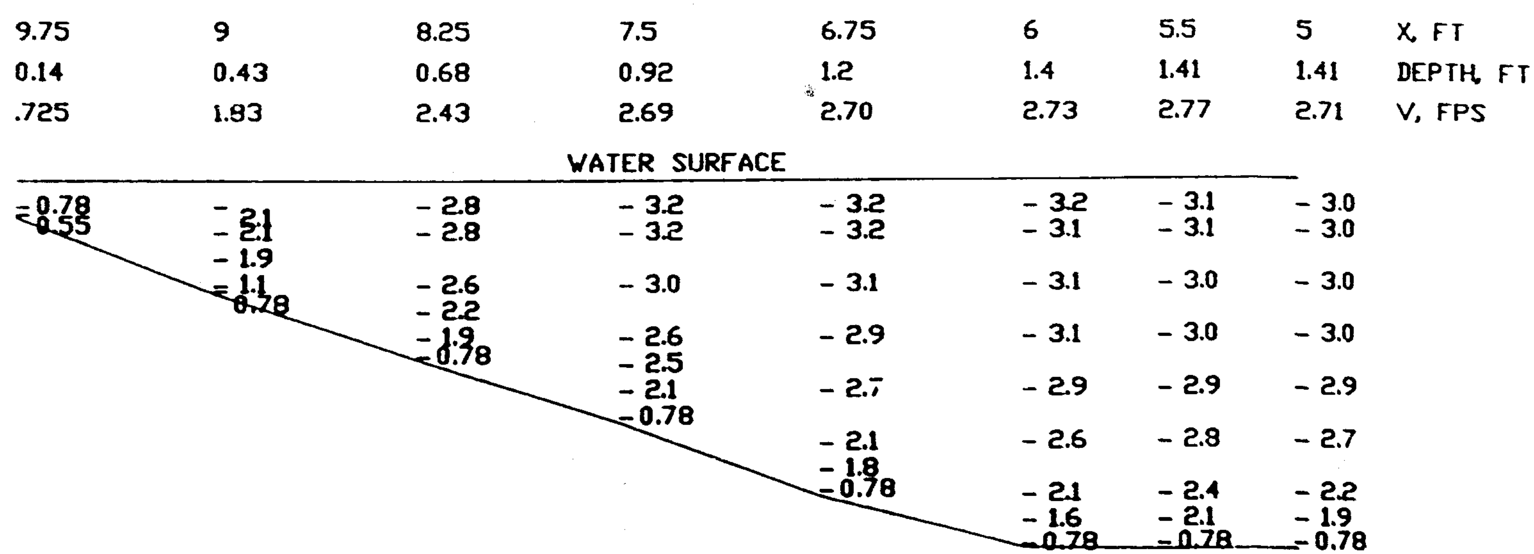
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.348

SIDE SLOPE VELOCITIES

TEST 403S306.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

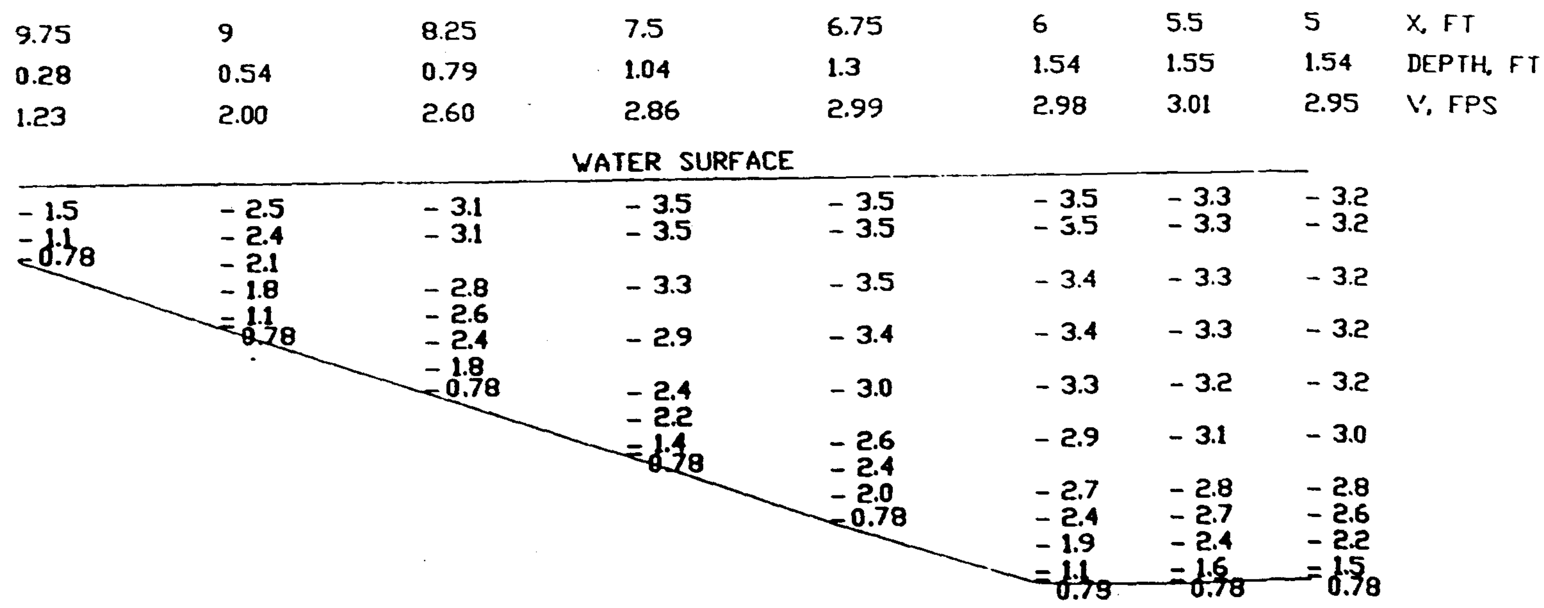
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.483

SIDE SLOPE VELOCITIES

TEST 453S306.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

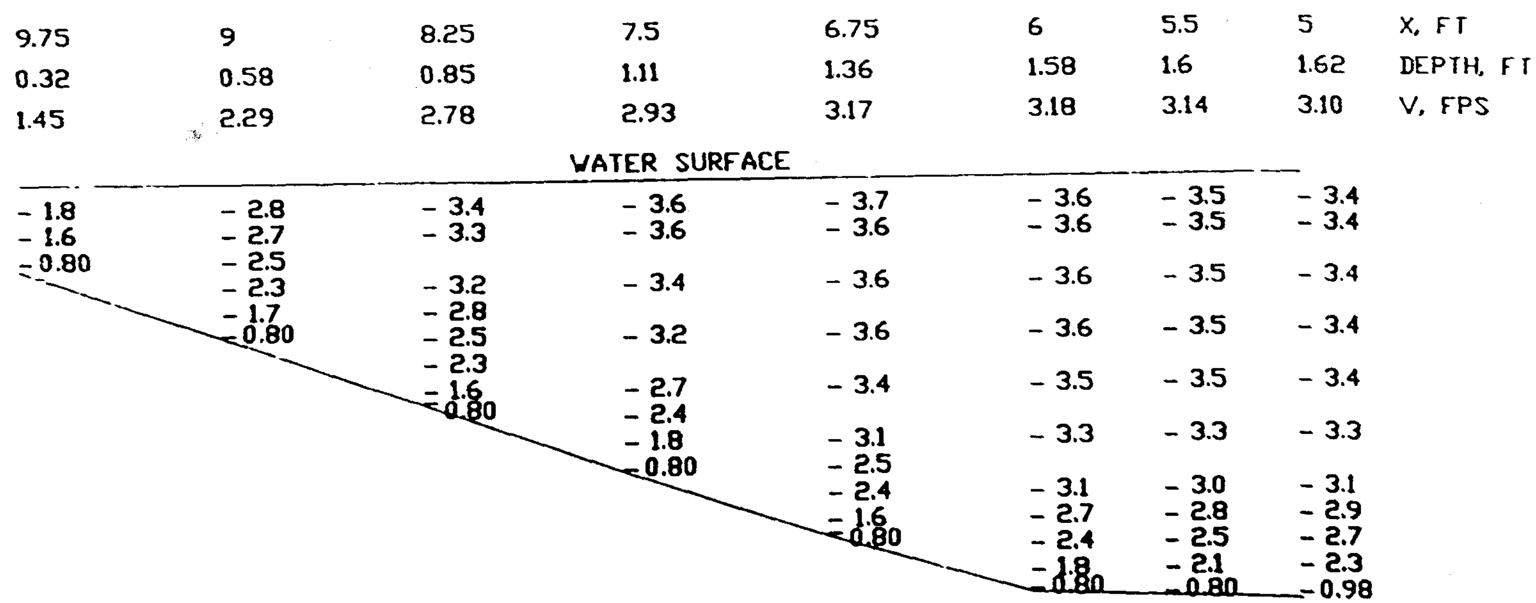
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.568

SIDE SLOPE VELOCITIES

TEST 503S306.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

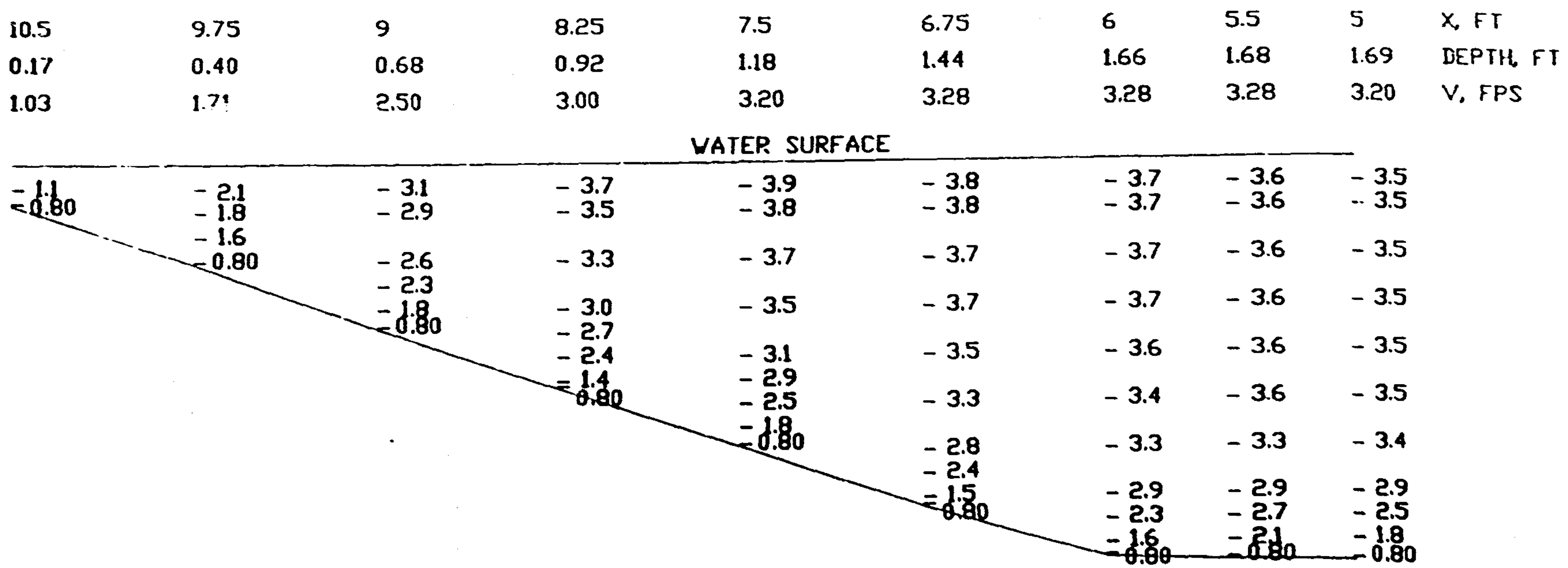
V = DEPTH-AVERAGED VELOCITY, FPS

\- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 18[illegible]

SIDE SLOPE VELOCITIES

TEST 553S306.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

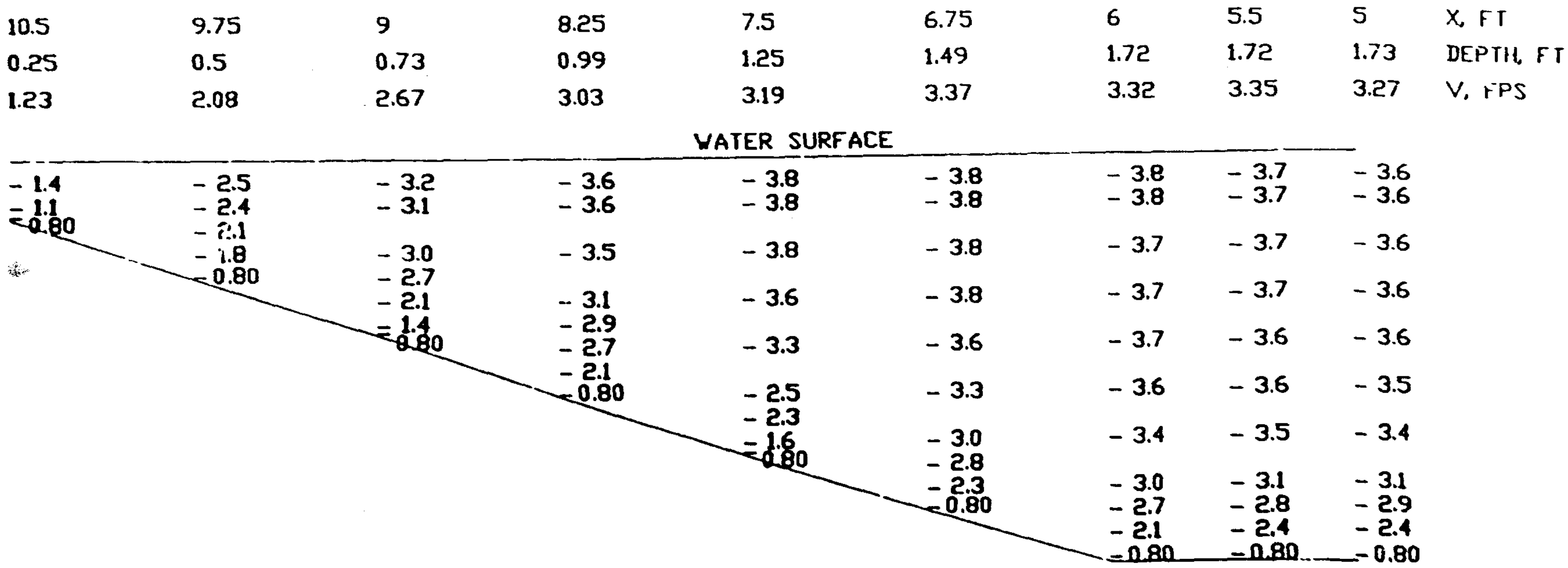
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.668

SIDE SLOPE VELOCITIES

TEST 603S306.GR6

PLATE A80



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

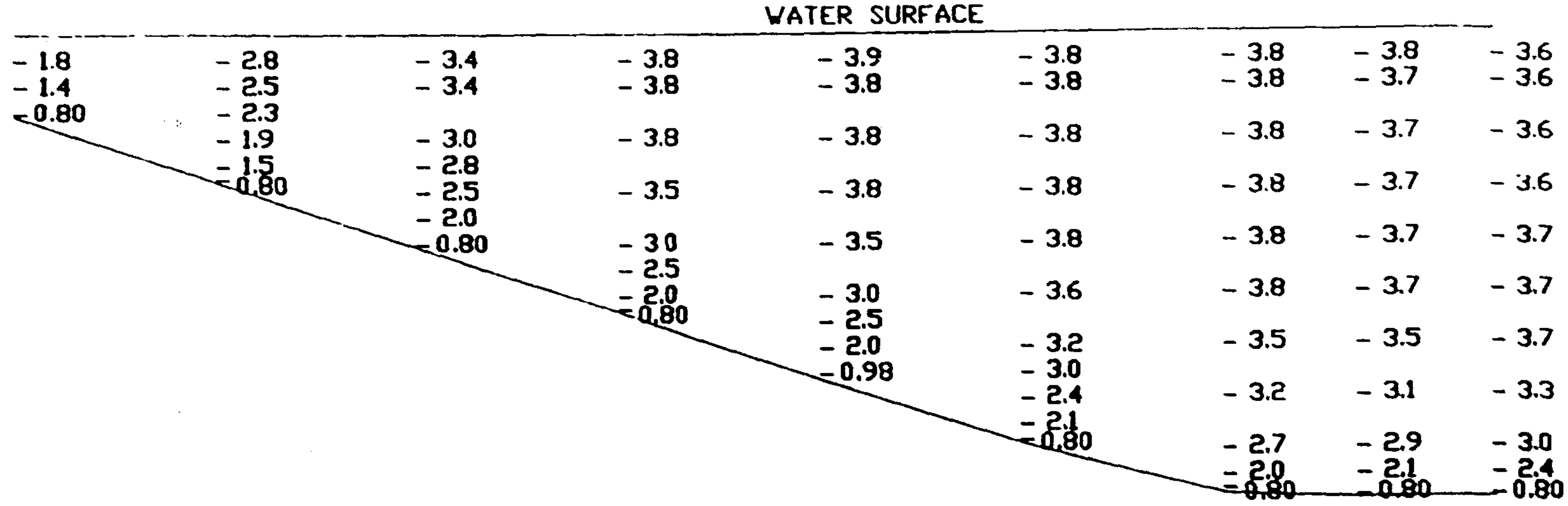
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.773

SIDE SLOPE VELOCITIES

TEST 653S306.GR6

10.5	9.75	9	8.25	7.5	6.75	6	5.5	5	X, FT
0.31	0.56	0.81	1.06	1.32	1.57	1.77	1.79	1.79	DEPTH, FT
1.45	2.18	2.76	3.28	3.29	3.41	3.41	3.37	3.39	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

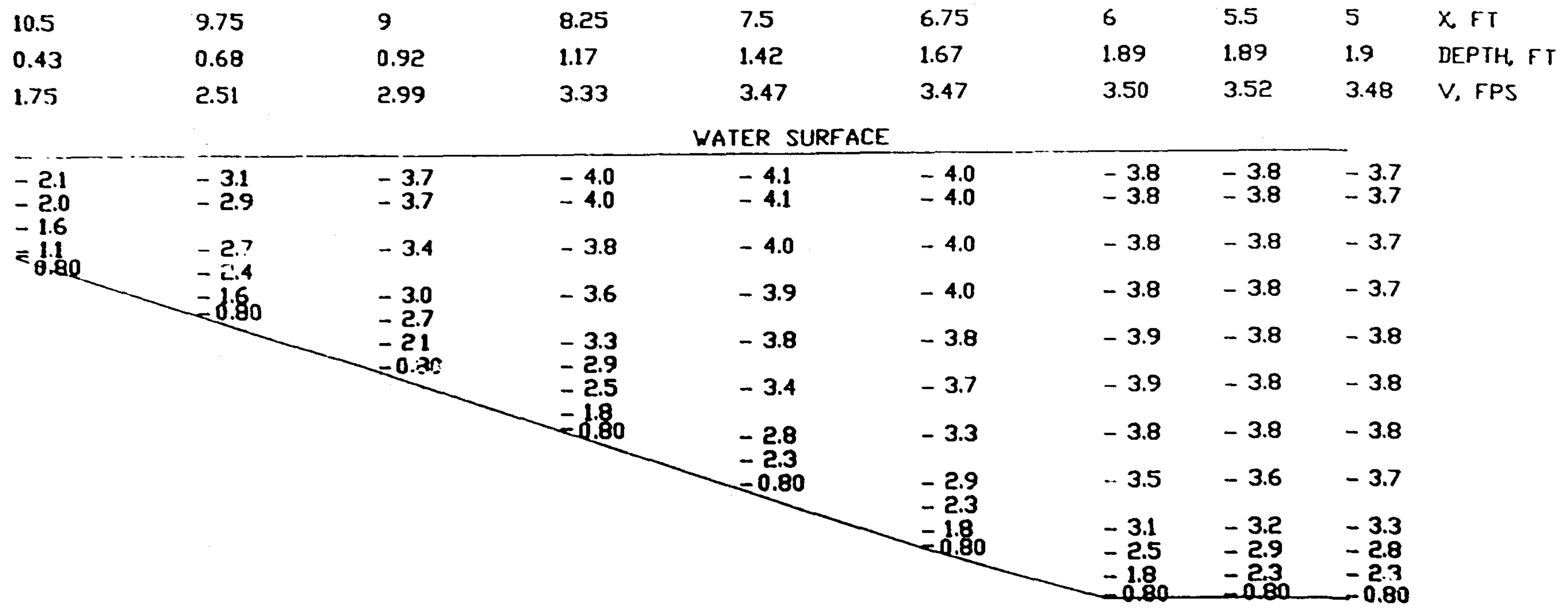
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.793

SIDE SLOPE VELOCITIES

TEST 703S306.GR6

PLATE A82



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

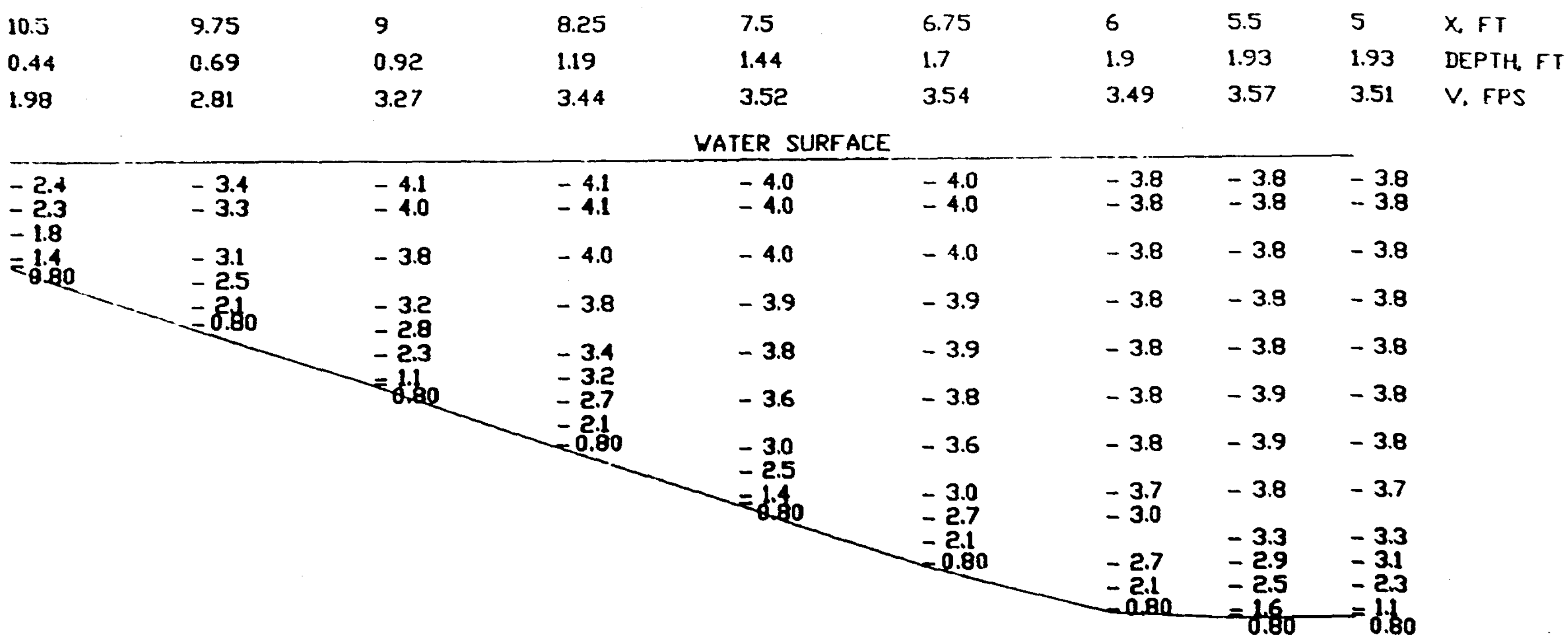
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.928

SIDE SLOPE VELOCITIES

TEST 753S306.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

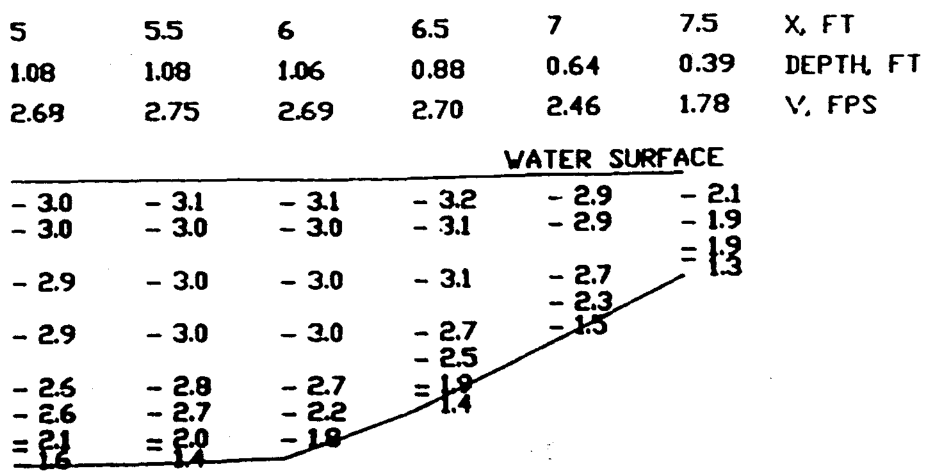
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.953

SIDE SLOPE VELOCITIES

TEST 803S306.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

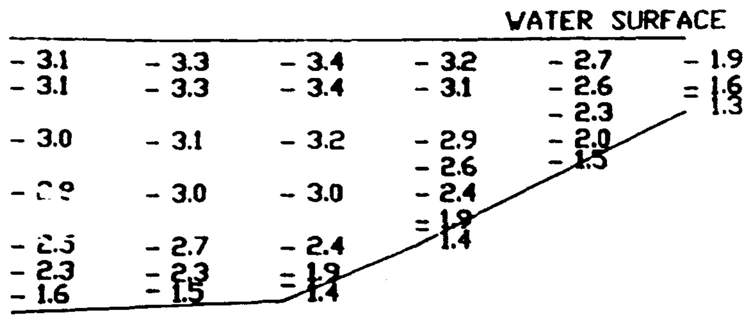
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.613

SIDE SLOPE VELOCITIES

TEST 302S578.GR6

5	5.5	6	6.5	7	7.5	X, FT
1.04	1.01	0.98	0.78	0.53	0.28	DEPTH, FT
2.68	2.82	2.81	2.62	2.19	1.56	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

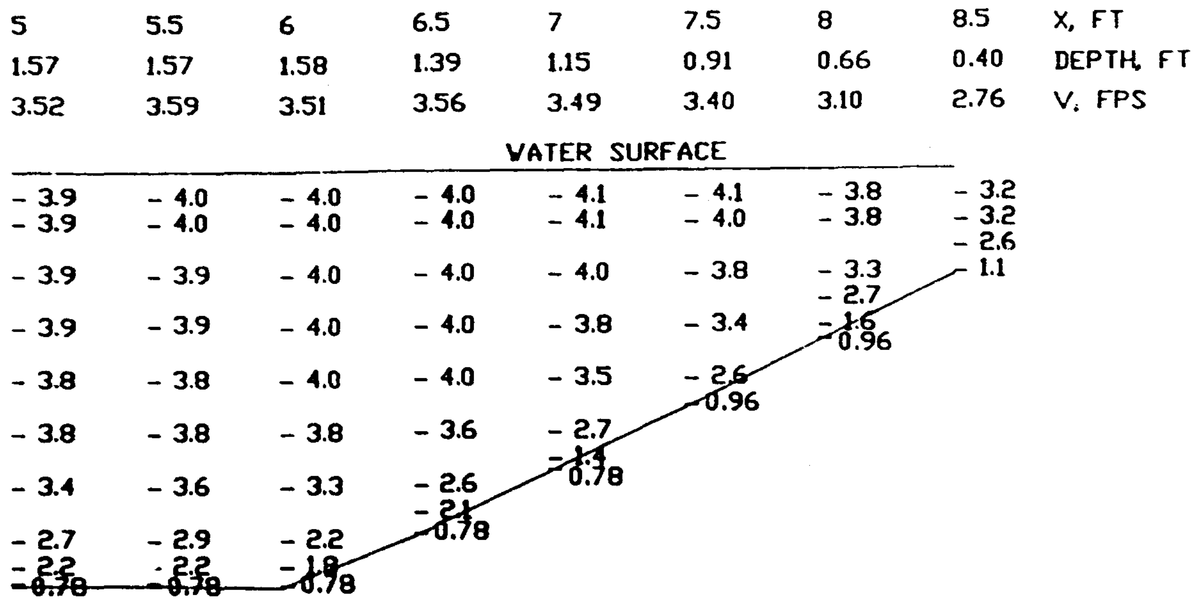
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.563

SIDE SLOPE VELOCITIES

TEST 302S602.GR6



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

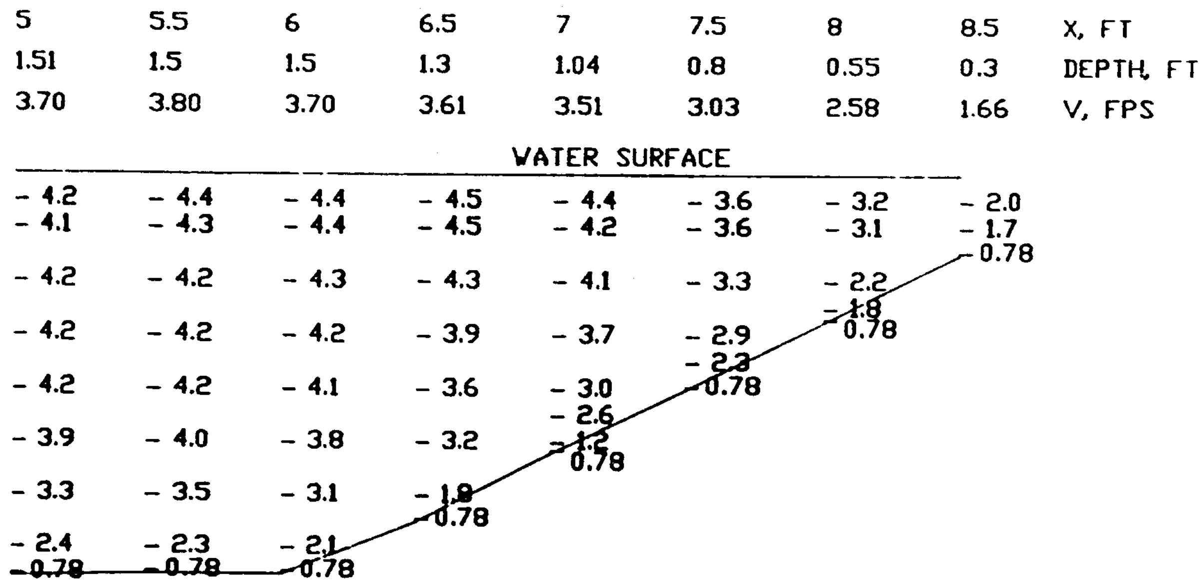
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.203

SIDE SLOPE VELOCITIES

TEST 652S578.GR7



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

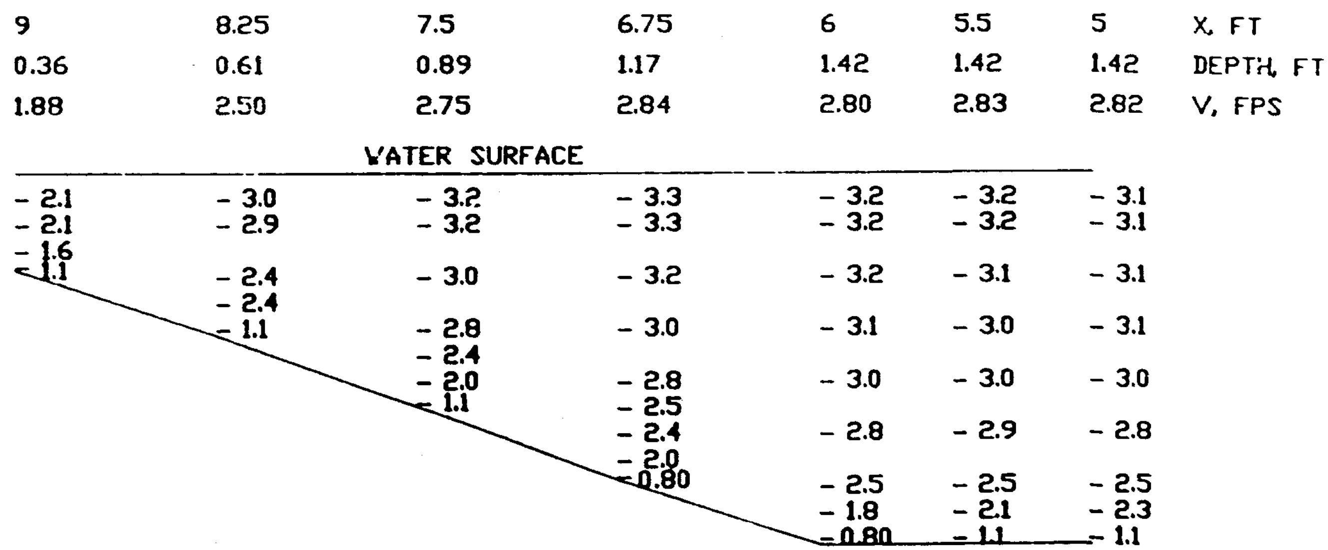
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.153

SIDE SLOPE VELOCITIES

TEST 652S602.GR7



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

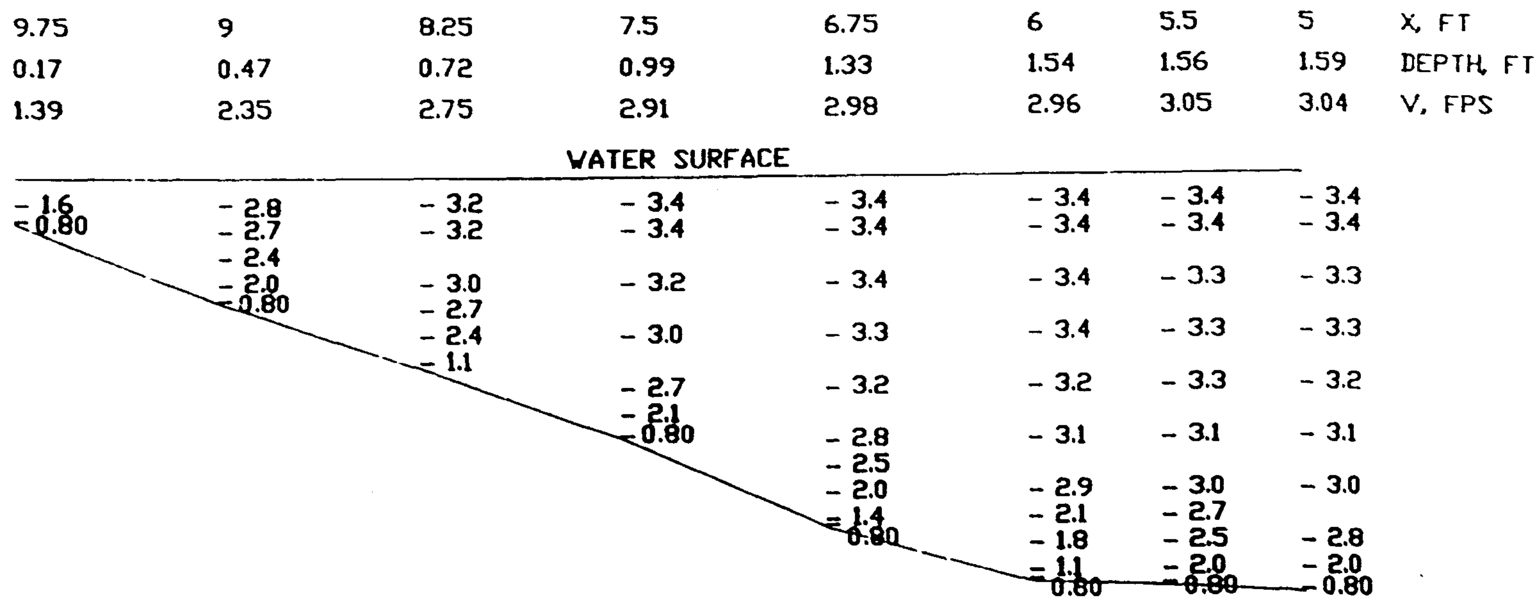
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.446

SIDE SLOPE VELOCITIES

TEST 453S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

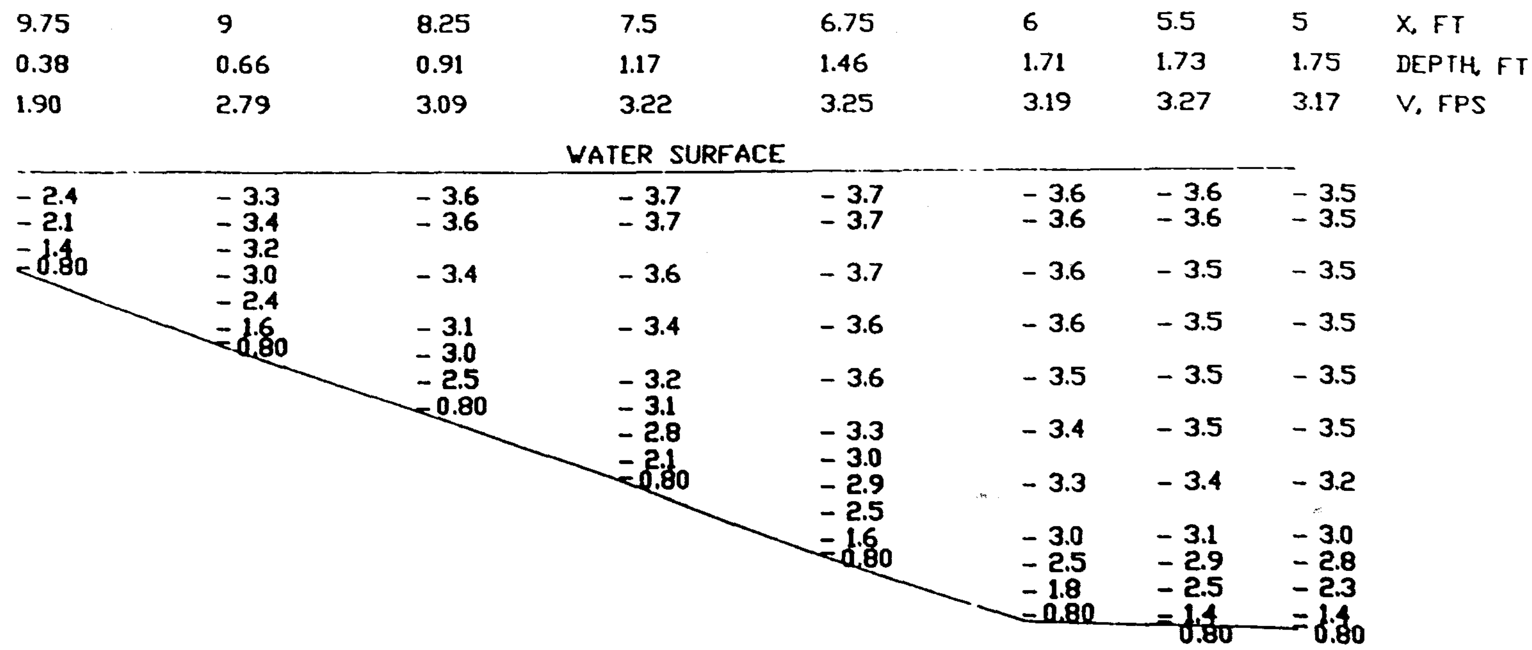
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.506

SIDE SLOPE VELOCITIES

TEST 503S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

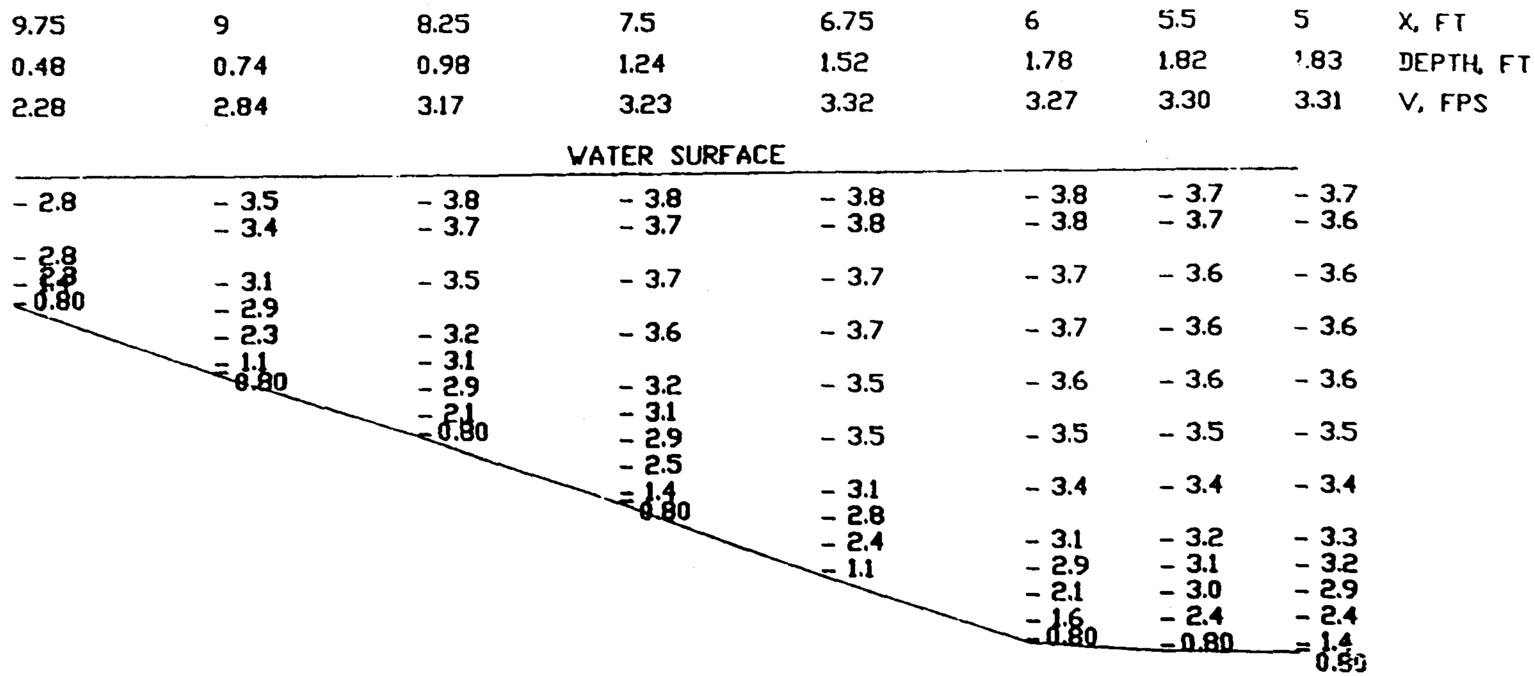
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.776

SIDE SLOPE VELOCITIES

TEST 653S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

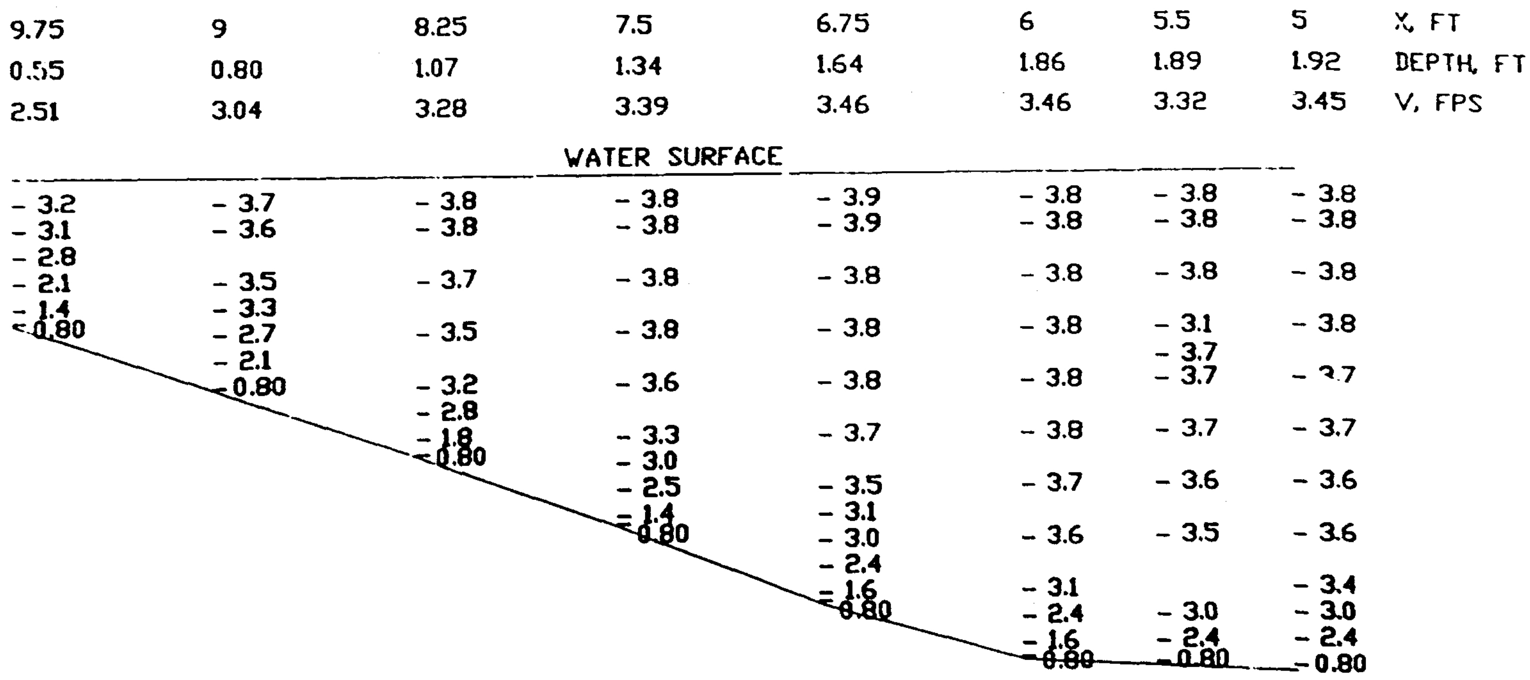
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.846

SIDE SLOPE VELOCITIES

TEST 703S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

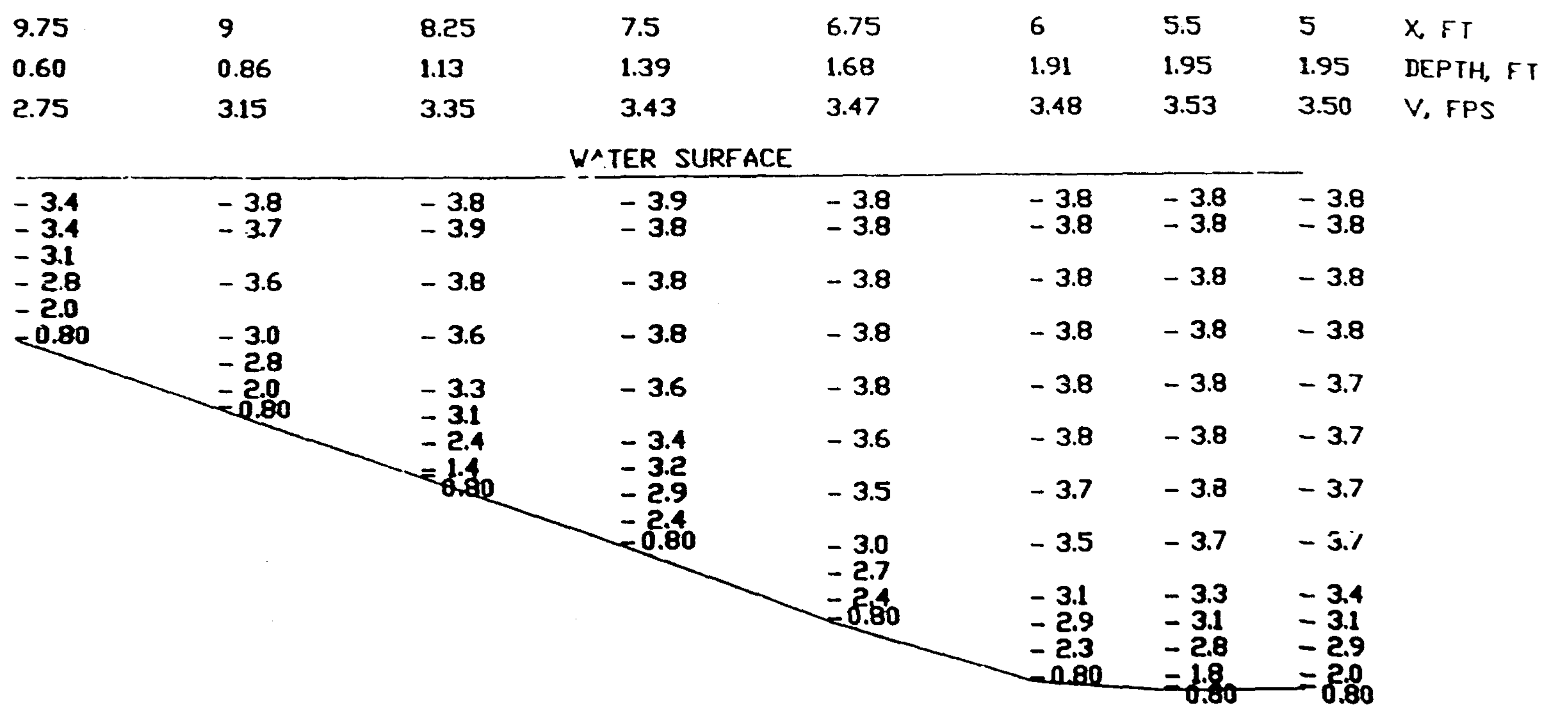
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.936

SIDE SLOPE VELOCITIES

TEST 753S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

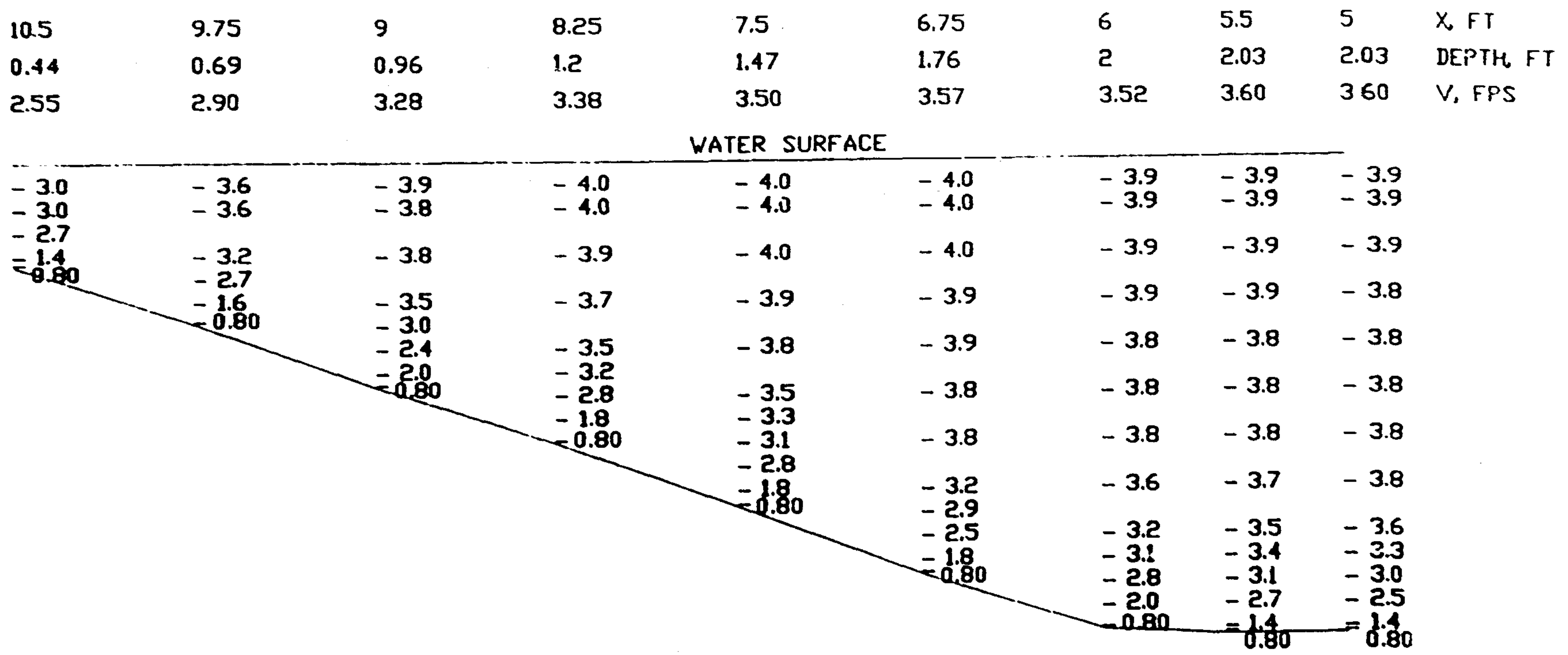
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.006

SIDE SLOPE VELOCITIES

TEST 803S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

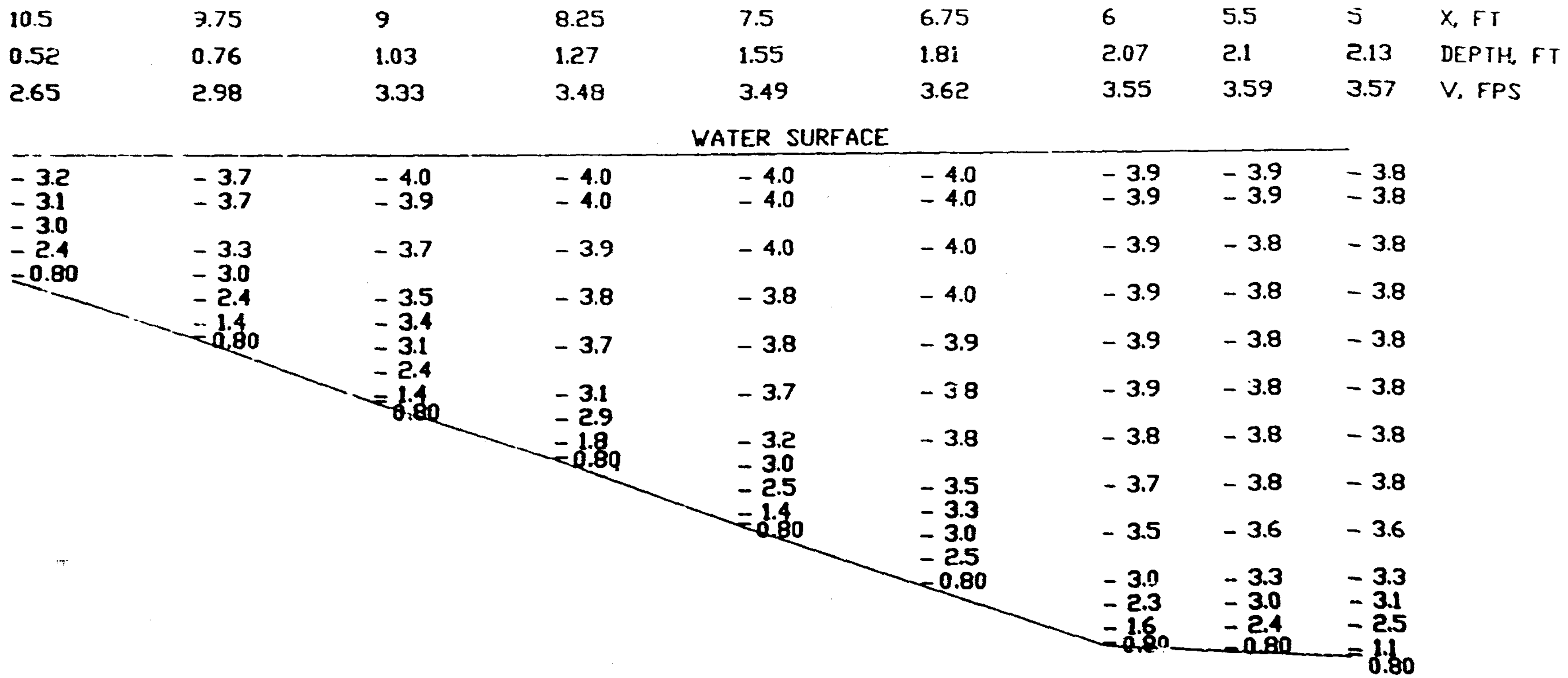
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.076

SIDE SLOPE VELOCITIES

TEST 853S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

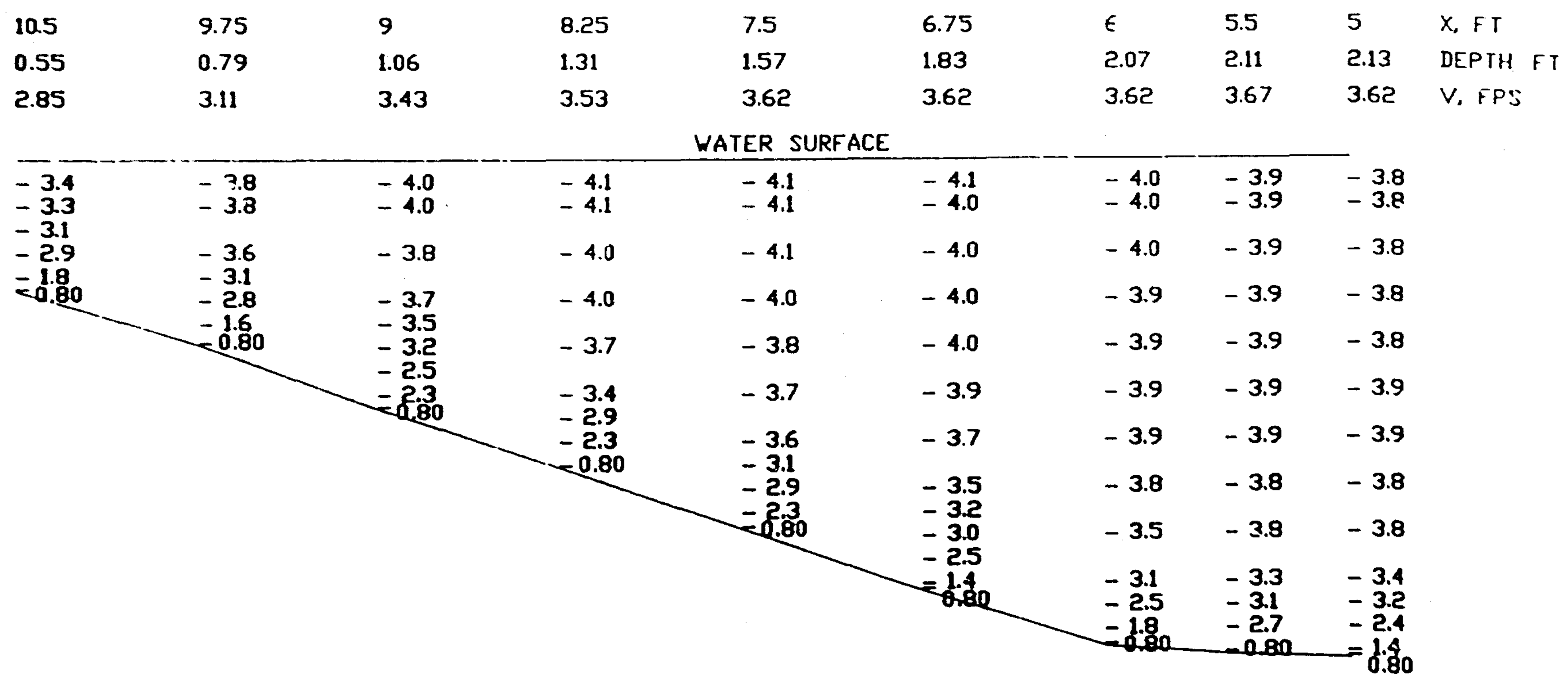
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.126

SIDE SLOPE VELOCITIES

TEST 903S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

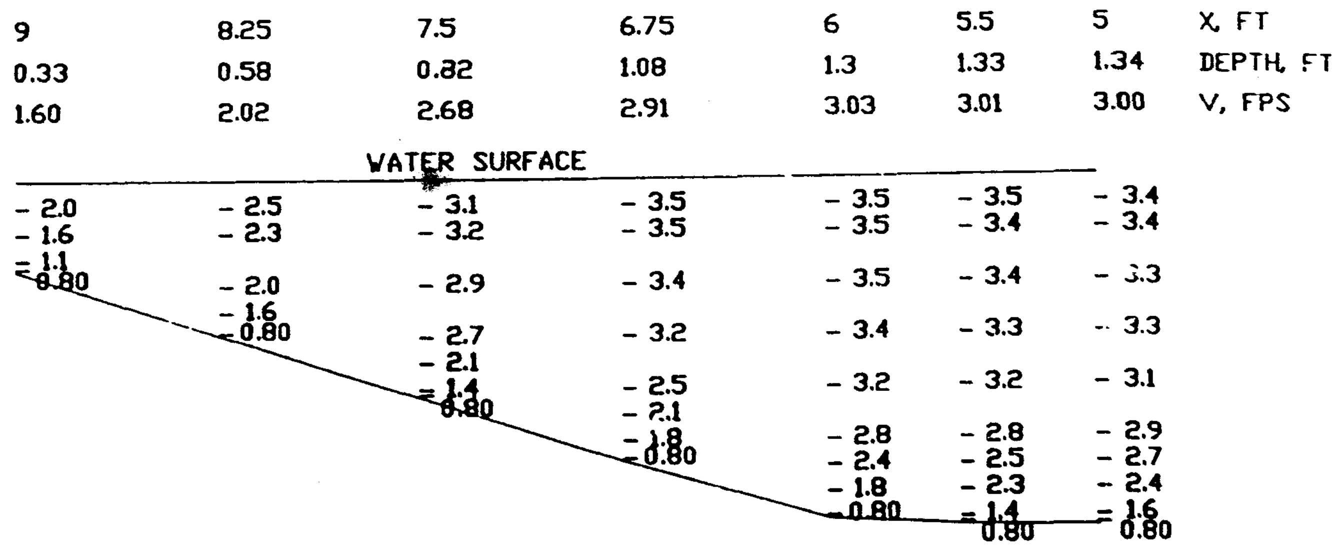
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.186

SIDE SLOPE VELOCITIES

TEST 953S281.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

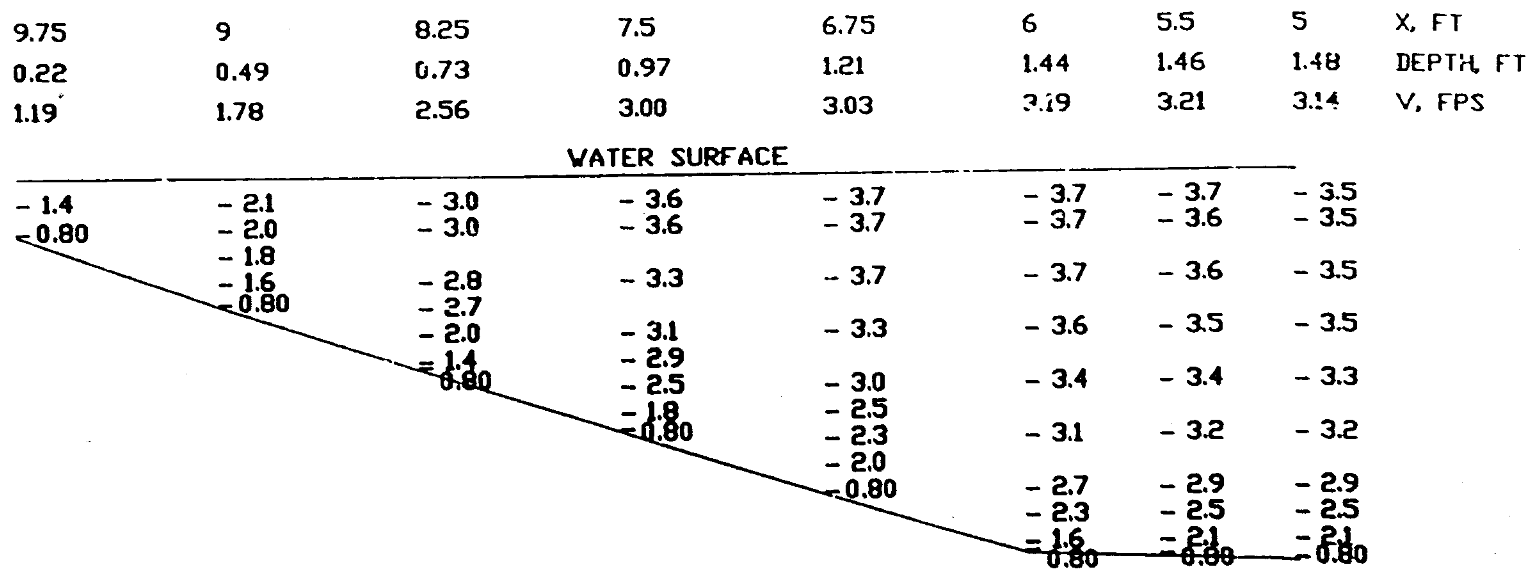
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.433

SIDE SLOPE VELOCITIES

TEST 45[illegible]306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

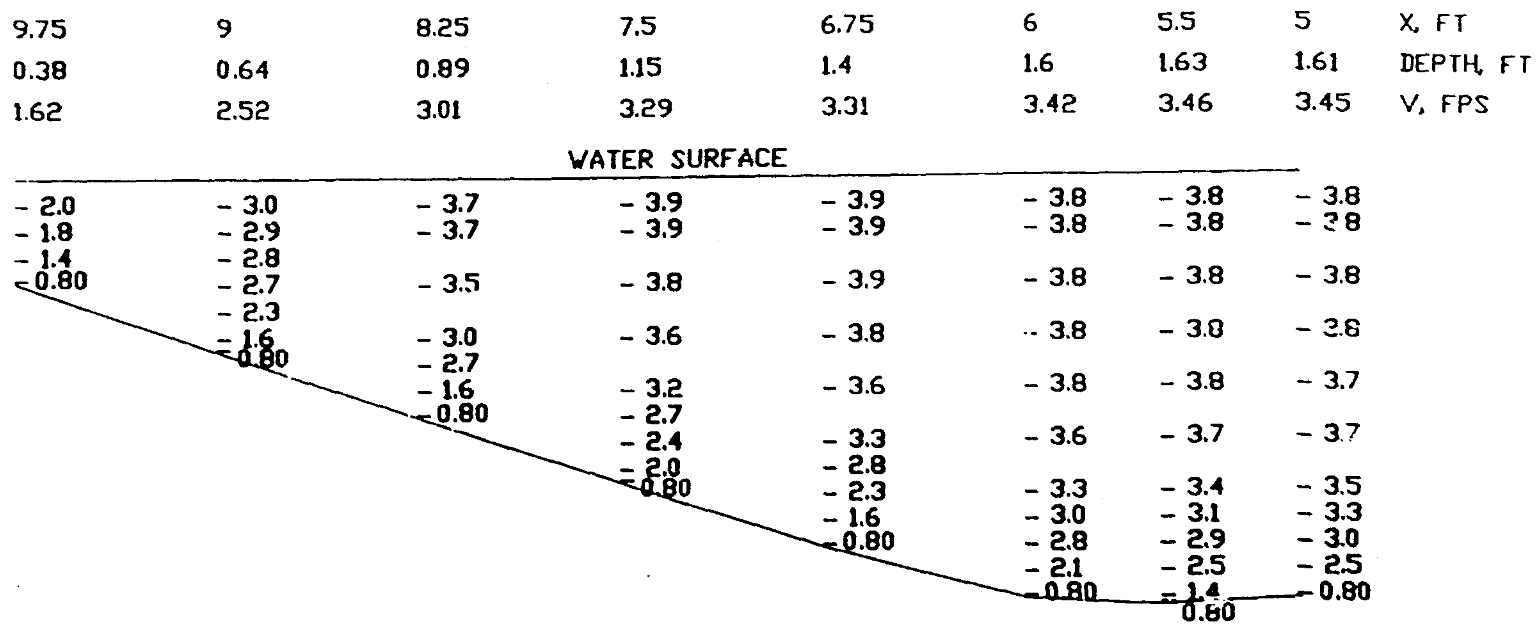
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.473

SIDE SLOPE VELOCITIES

TEST 503S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

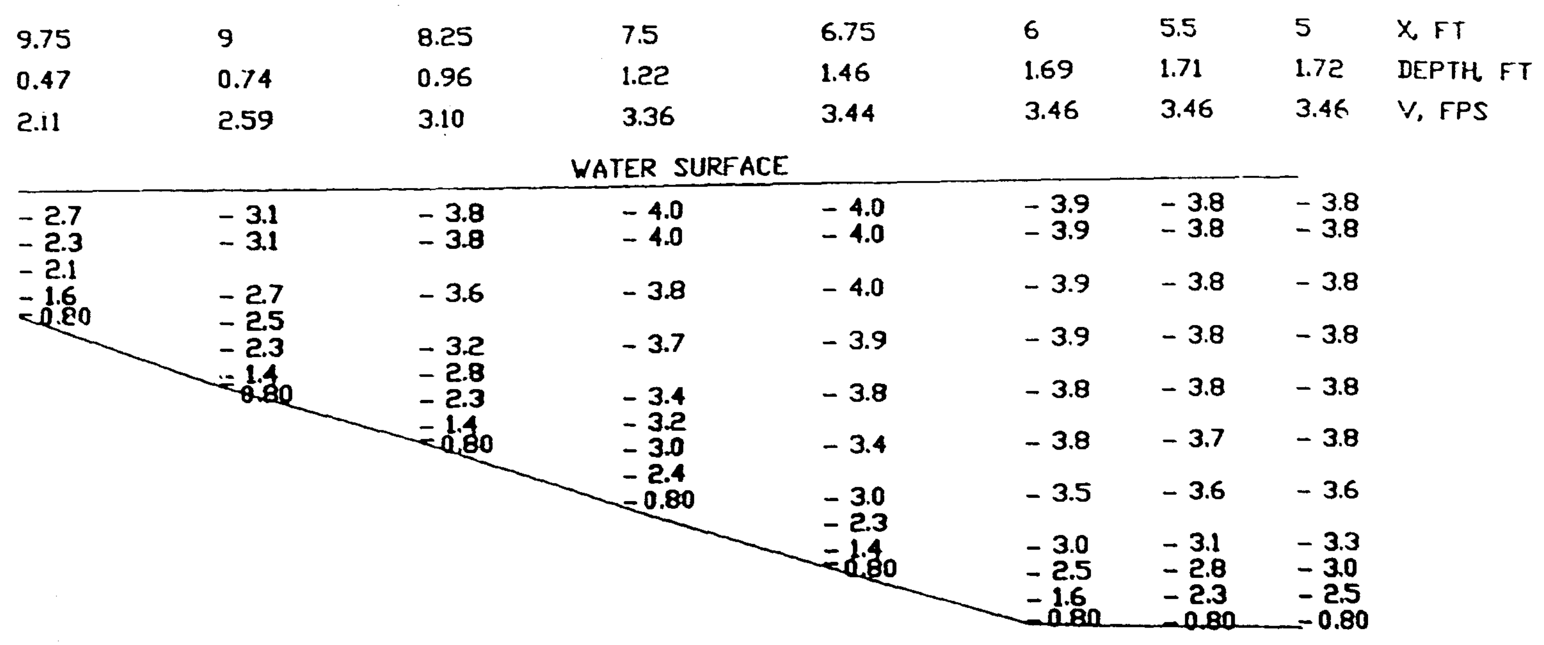
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.753

SIDE SLOPE VELOCITIES

TEST 653S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

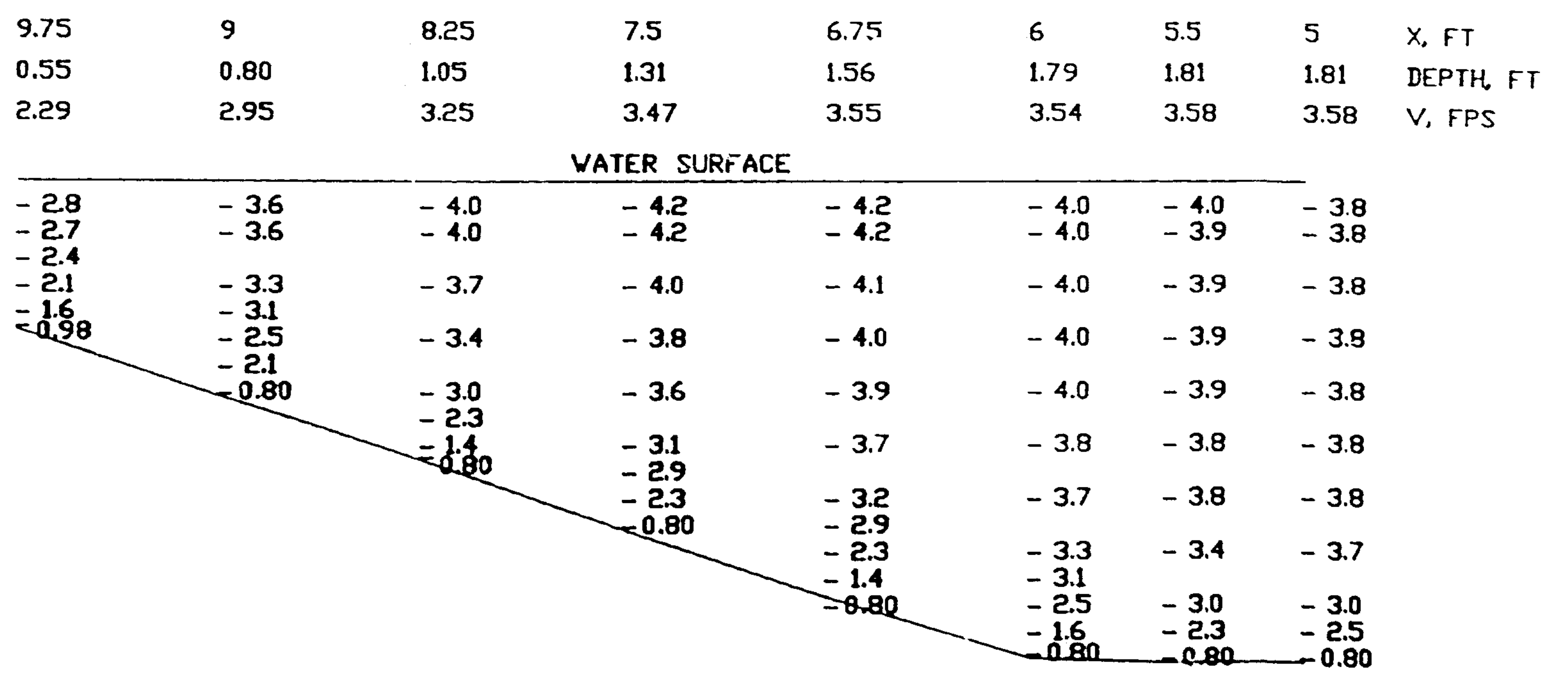
V = DEPTH-AVERAGED VELOCITY, FPS

3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.813

SIDE SLOPE VELOCITIES

TEST 703S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

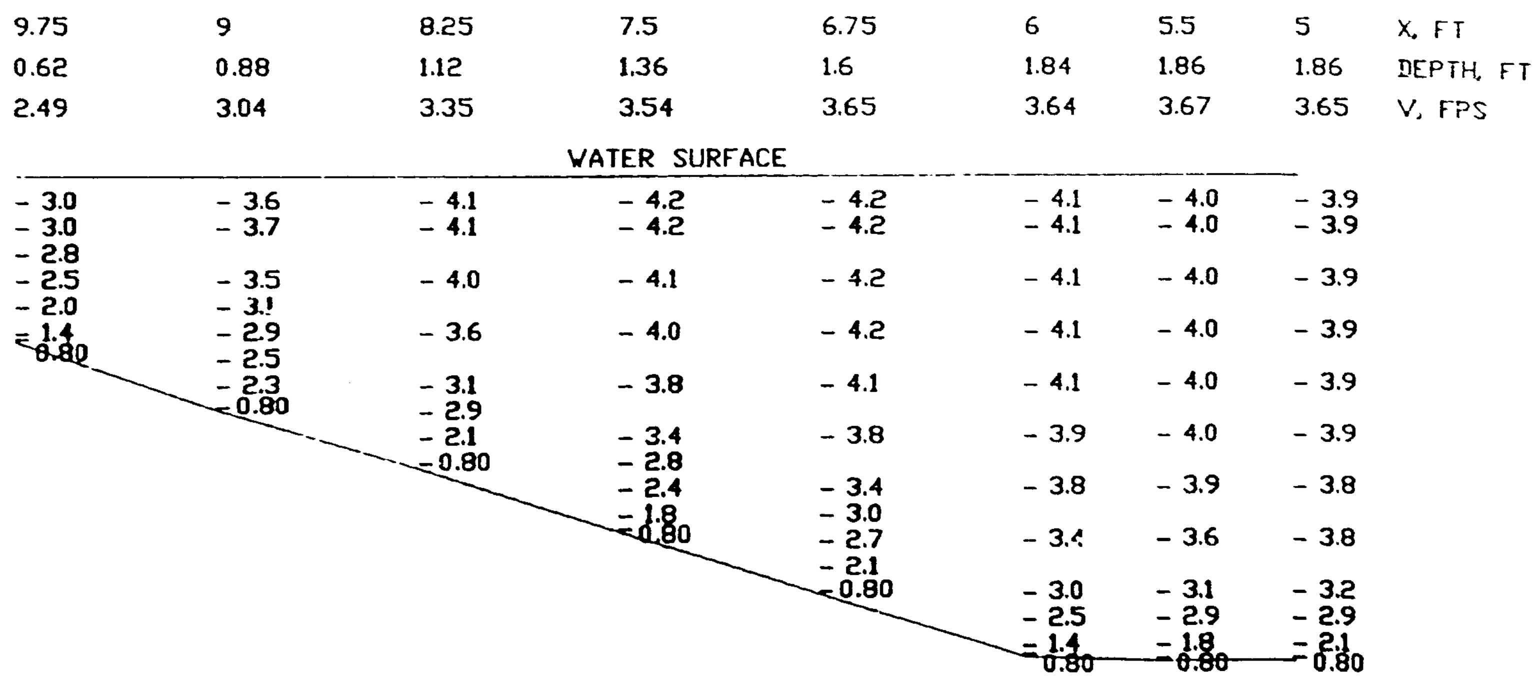
V = DEPTH-AVERAGFD VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: VATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.923

SIDE SLOPE VELOCITIES

TEST 753S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

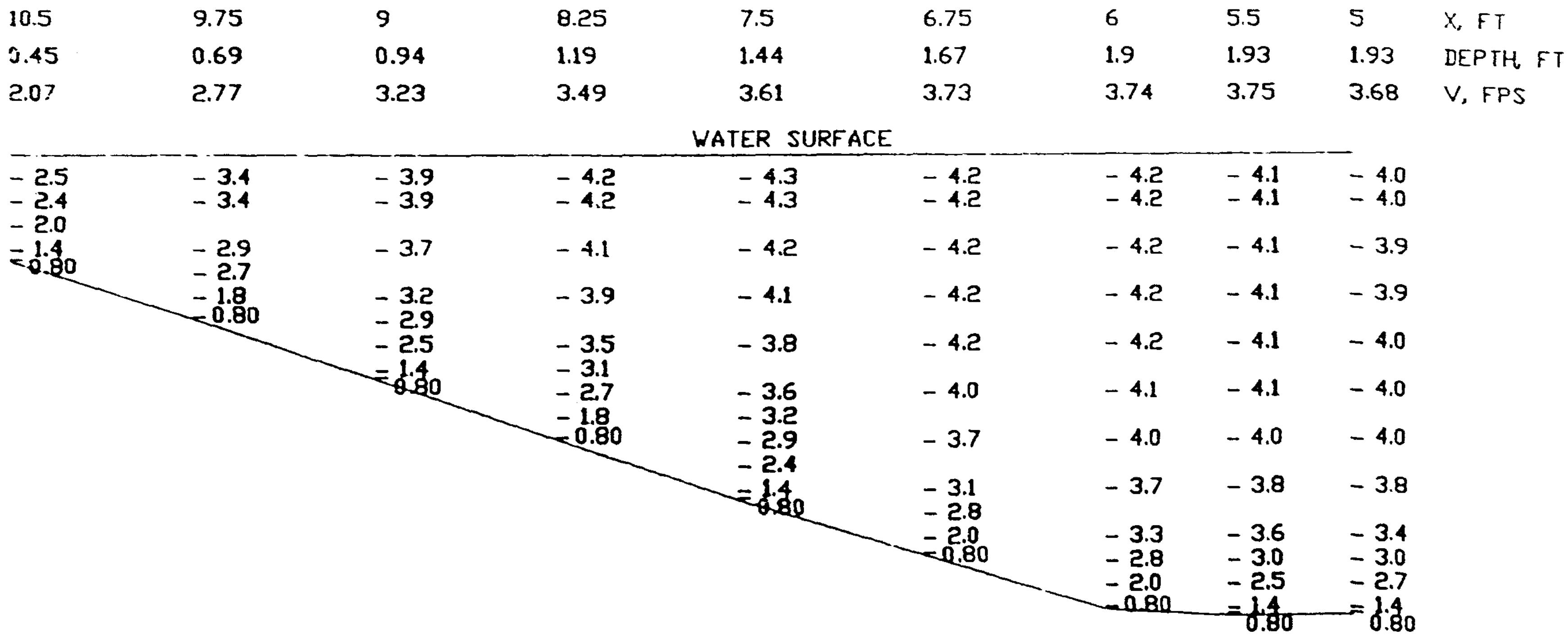
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.973

SIDE SLOPE VELOCITIES

TEST 803S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

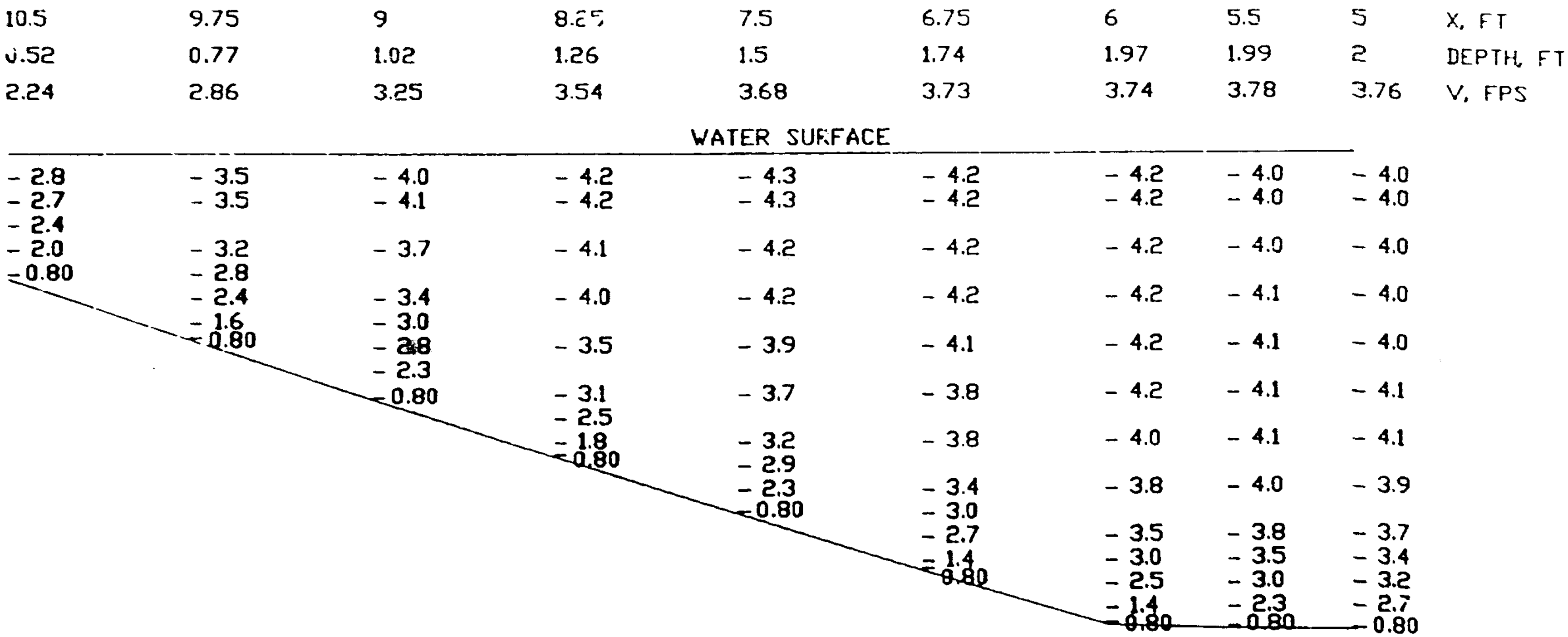
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.063

SIDE SLOPE VELOCITIES

TEST 853S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

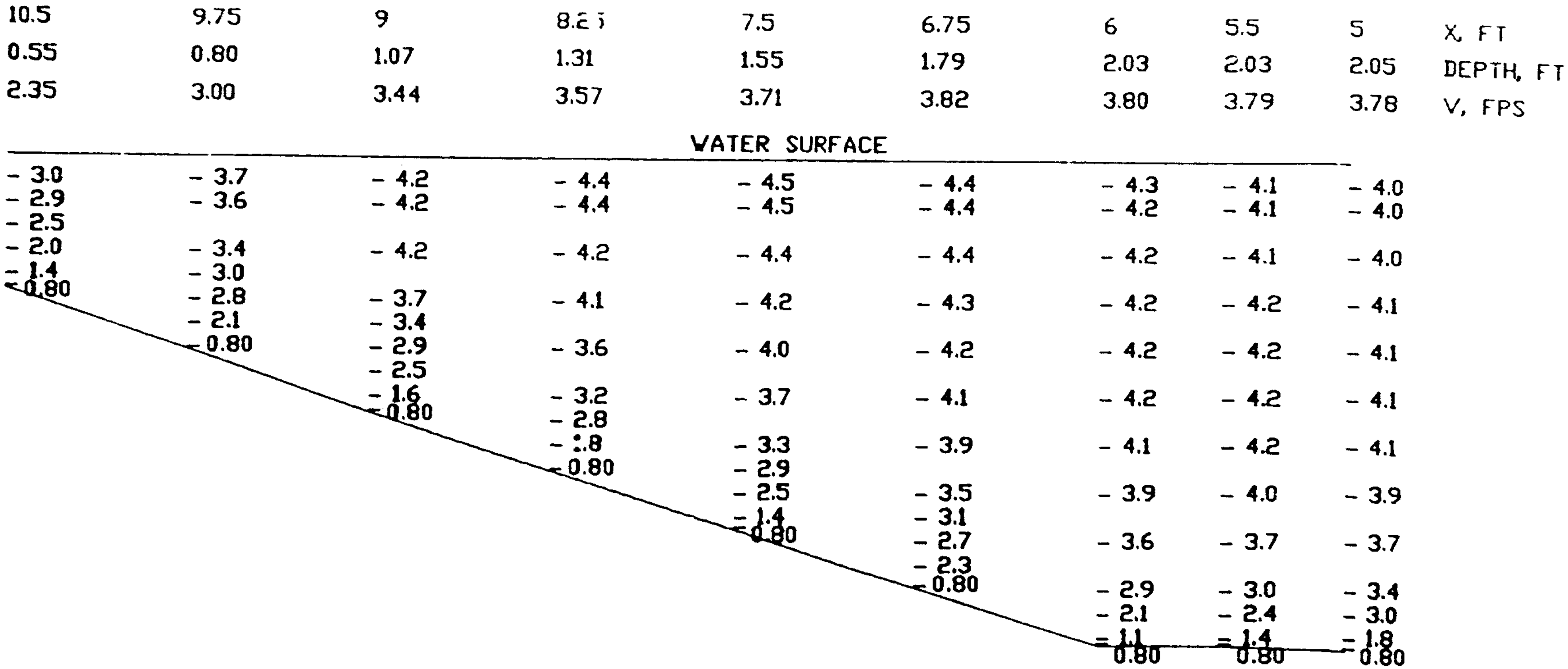
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.103

SIDE SLOPE VELOCITIES

TEST 903S306.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

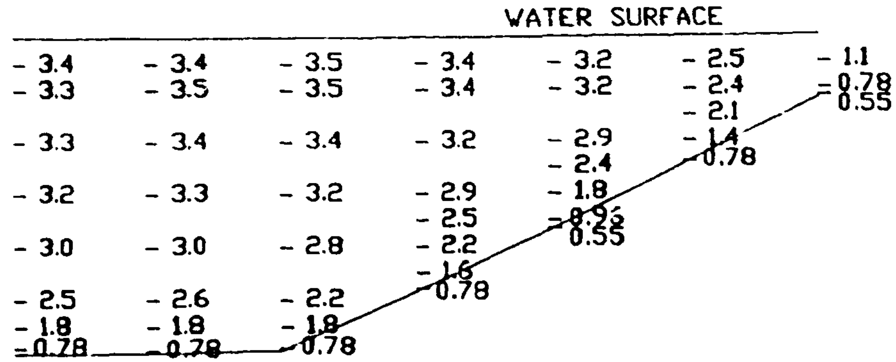
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 181.173

SIDE SLOPE VELOCITIES

TEST 953S306.GR8

5	5.5	6	6.5	7	7.5	8	X, FT
1.2	1.2	1.19	0.97	0.74	0.49	0.24	DEPTH, FT
2.92	2.99	2.92	2.81	2.56	1.98	.953	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

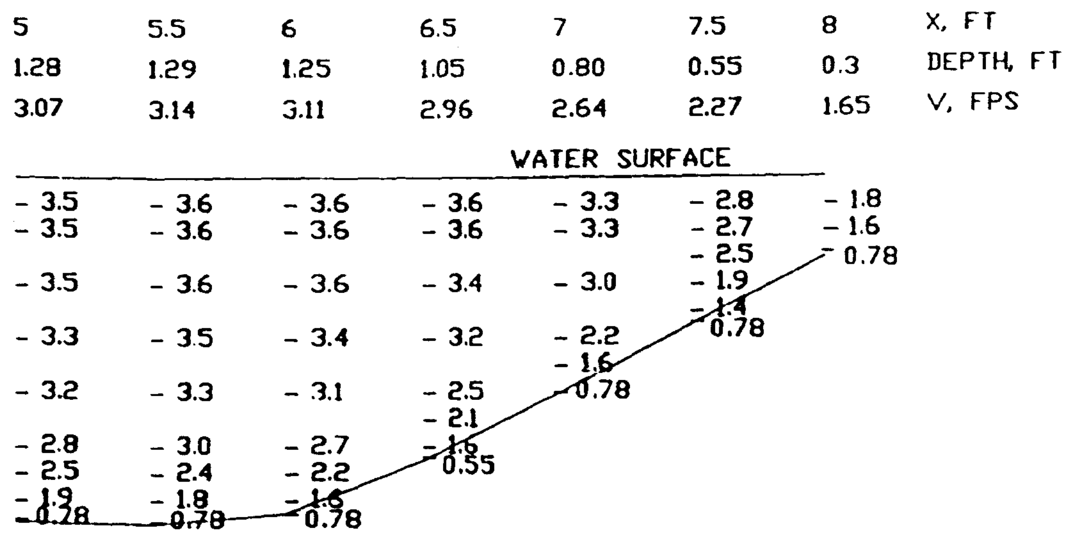
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.823

SIDE SLOPE VELOCITIES

TEST 402S578.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.903

SIDE SLOPE VELOCITIES

TEST 452S578.GR8

5	5.5	6	6.5	7	7.5	8	X, FT
1.42	1.43	1.42	1.21	0.98	0.73	0.47	DEPTH, FT
3.26	3.21	3.15	3.09	2.94	2.74	2.18	V, FPS
				WATER SURFACE			
- 3.7	- 3.7	- 3.8	- 3.8	- 3.8	- 3.5	- 2.7	
- 3.7	- 3.7	- 3.8	- 3.8	- 3.8	- 3.5	- 2.7	
						- 2.1	
- 3.7	- 3.7	- 3.7	- 3.7	- 3.3	- 3.2	- 1.4	
					- 2.4	- 0.78	
- 3.6	- 3.6	- 3.6	- 3.4	- 3.1	- 1.6		
				- 2.5	- 0.78		
- 3.6	- 3.5	- 3.4	- 3.2	- 2.2			
			- 2.8	- 1.4			
- 3.2	- 3.2	- 3.1	- 2.4	- 0.78			
- 3.0	- 2.9	- 2.8	- 1.6				
- 2.8	- 2.6	- 2.4	- 0.55				
- 2.2	- 2.2	- 1.6					
- 0.78	- 0.78	- 0.78					

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

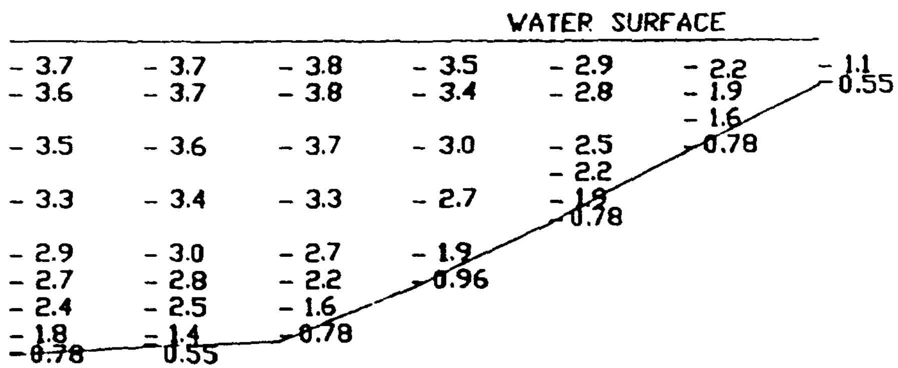
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.043

SIDE SLOPE VELOCITIES

TEST 502S578.GR8

5	5.5	6	6.5	7	7.5	8	X, FT
1.17	1.14	1.12	0.92	0.68	0.42	0.17	DEPTH, FT
3.06	3.17	3.00	2.76	2.42	1.73	.964	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

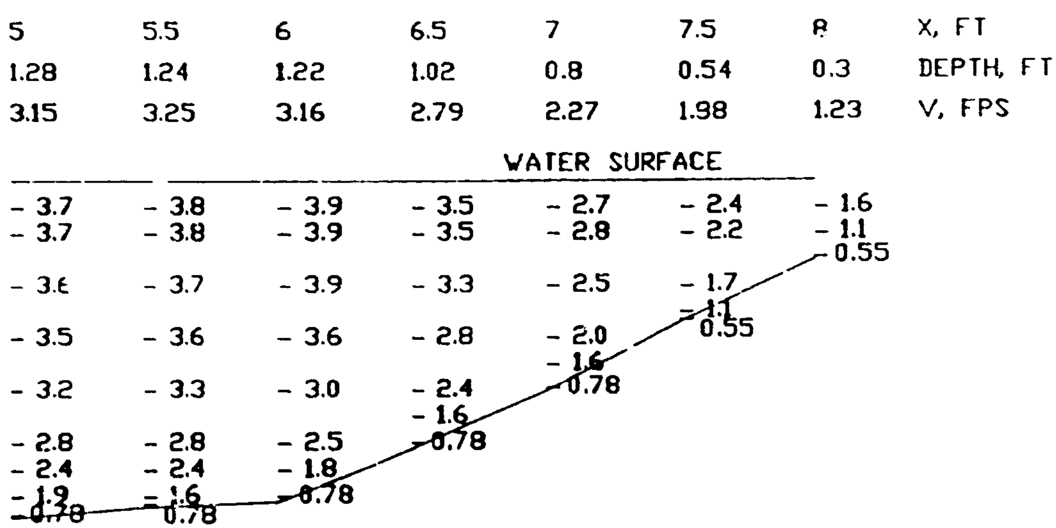
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.773

SIDE SLOPE VELOCITIES

TEST 402S602.GR8



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

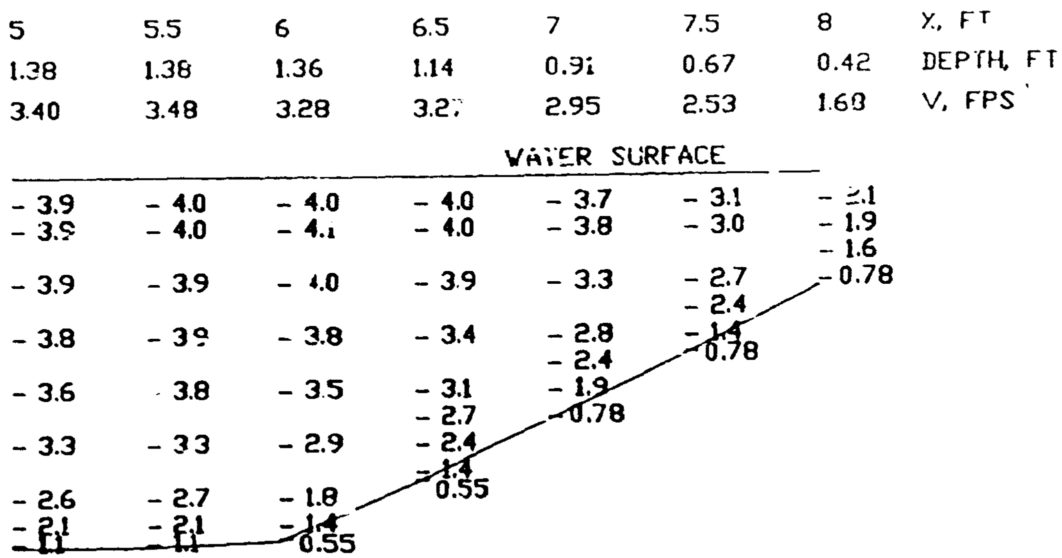
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.853

SIDE SLOPE VELOCITIES

TEST 452S602.GR8



LEGEND.

X = DISTANCE FROM CHANNEL CENTER LINE, FT

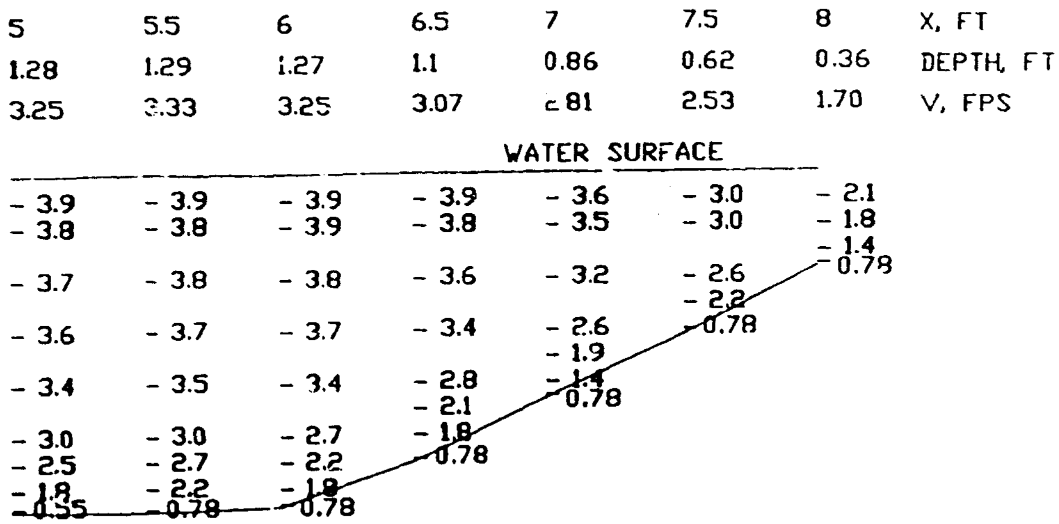
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.000

SIDE SLOPE VELOCITIES

TEST 502S602.GR8



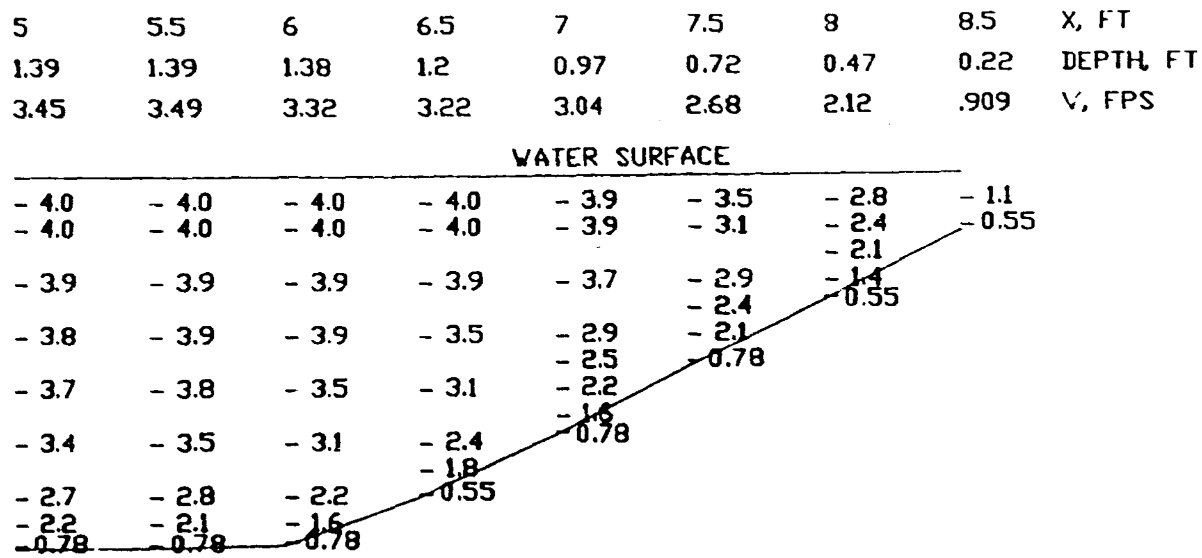
LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT
V = DEPTH-AVERAGED VELOCITY, FPS
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.993

SIDE SLOPE VELOCITIES

TEST 502S578.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

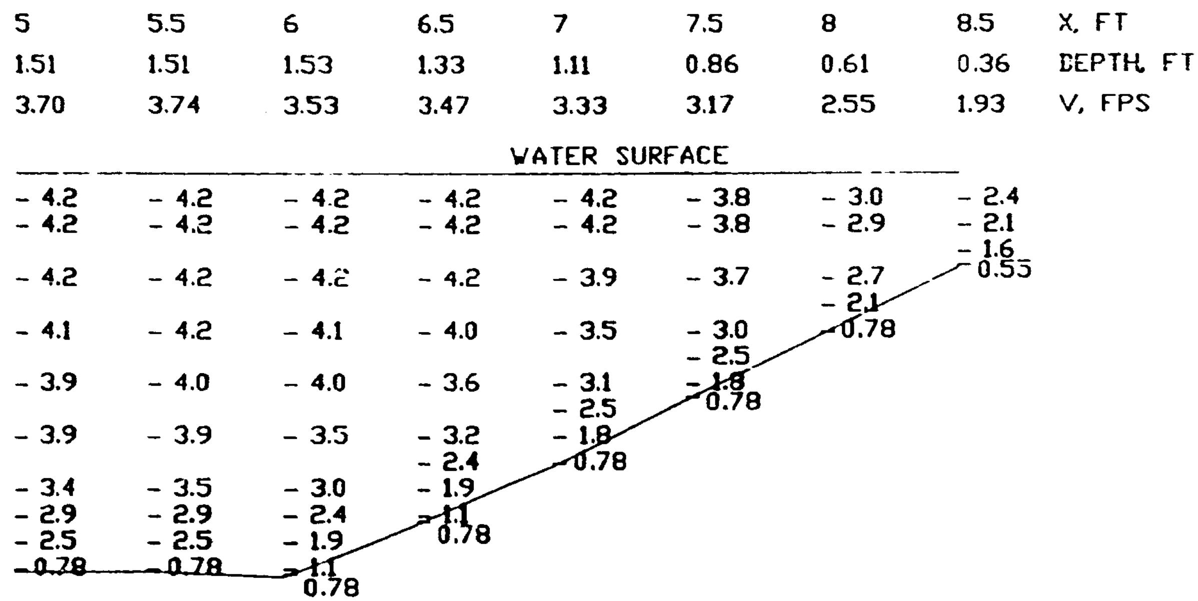
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.123

SIDE SLOPE VELOCITIES

TEST 602S578.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

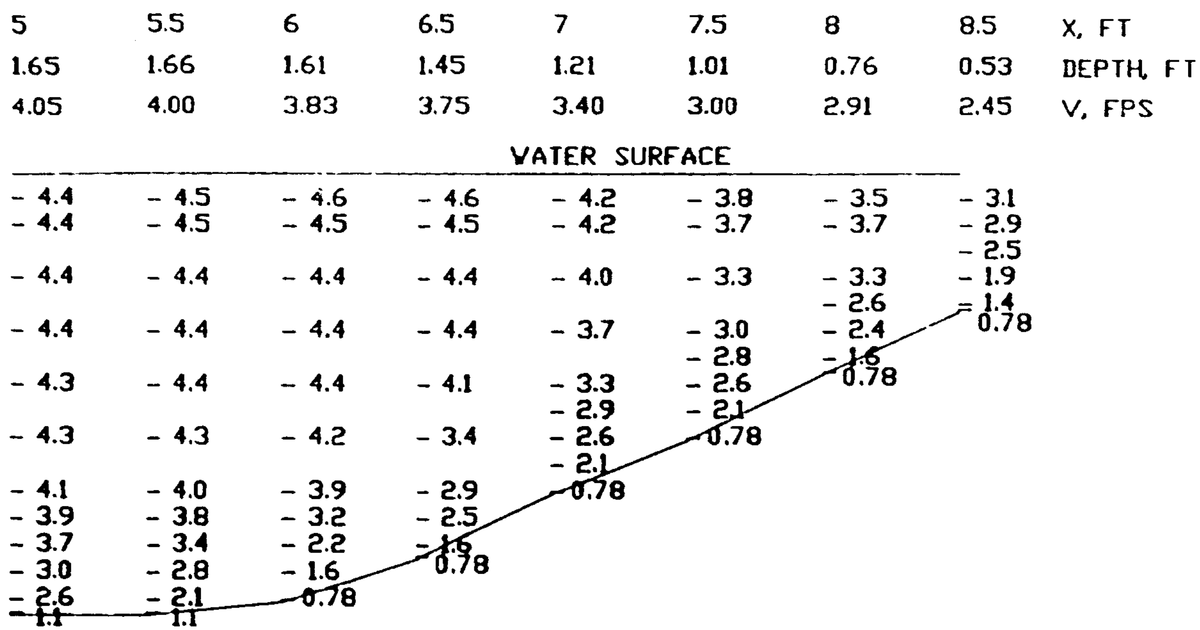
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.273

SIDE SLOPE VELOCITIES

TEST 702S578.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

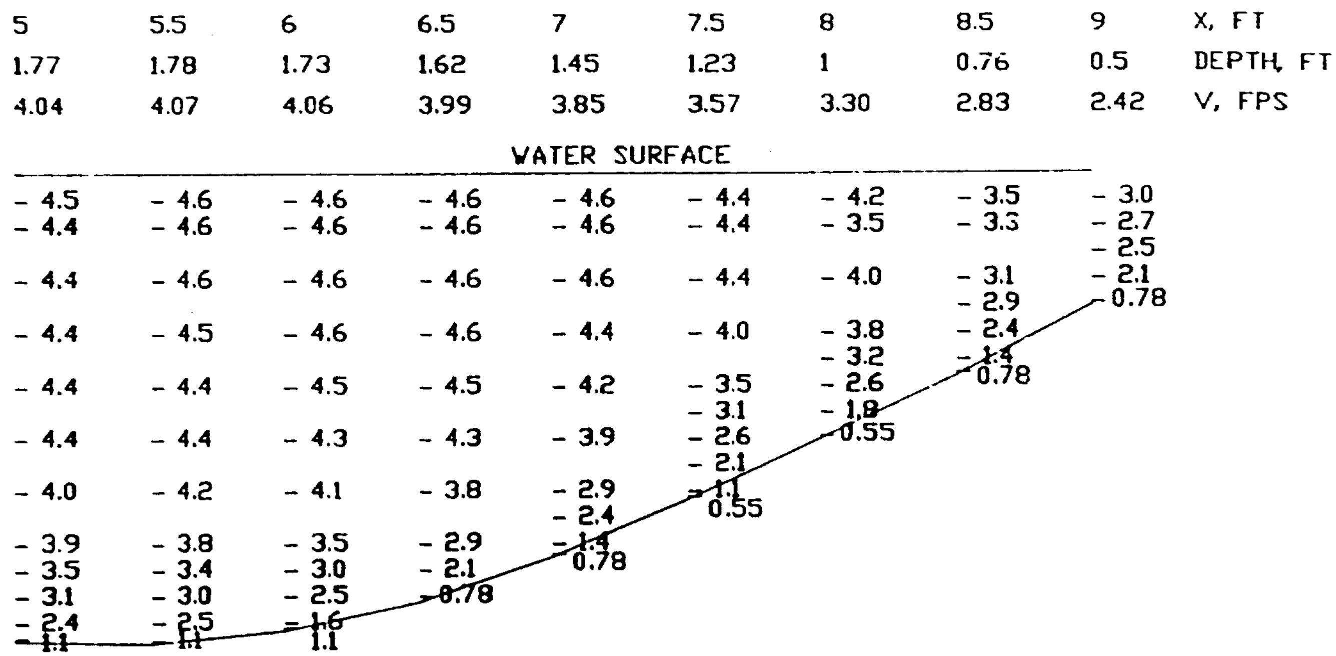
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: VATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.428

SIDE SLOPE VELOCITIES

TEST 802S578.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

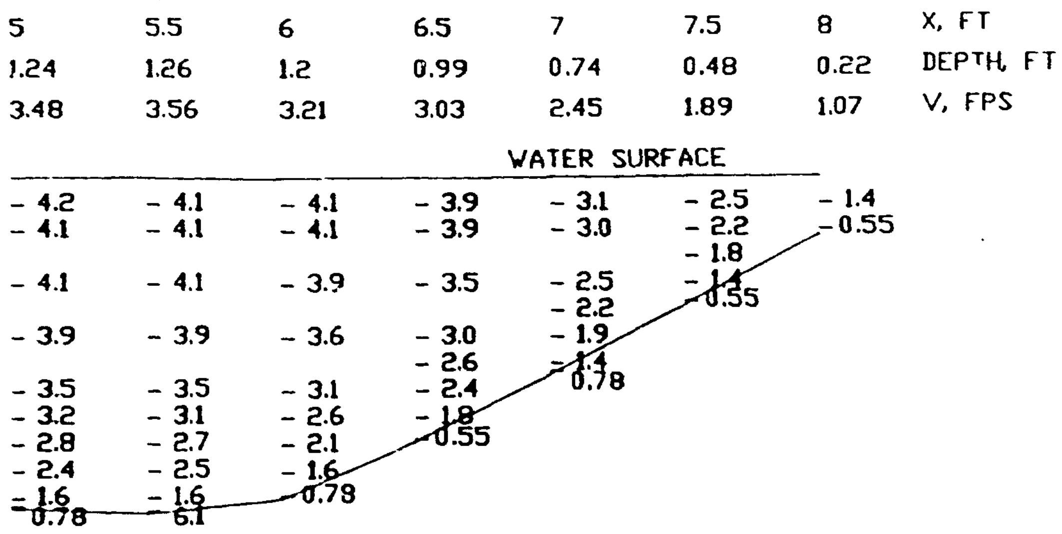
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.543

SIDE SLOPE VELOCITIES

TEST 902S578.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

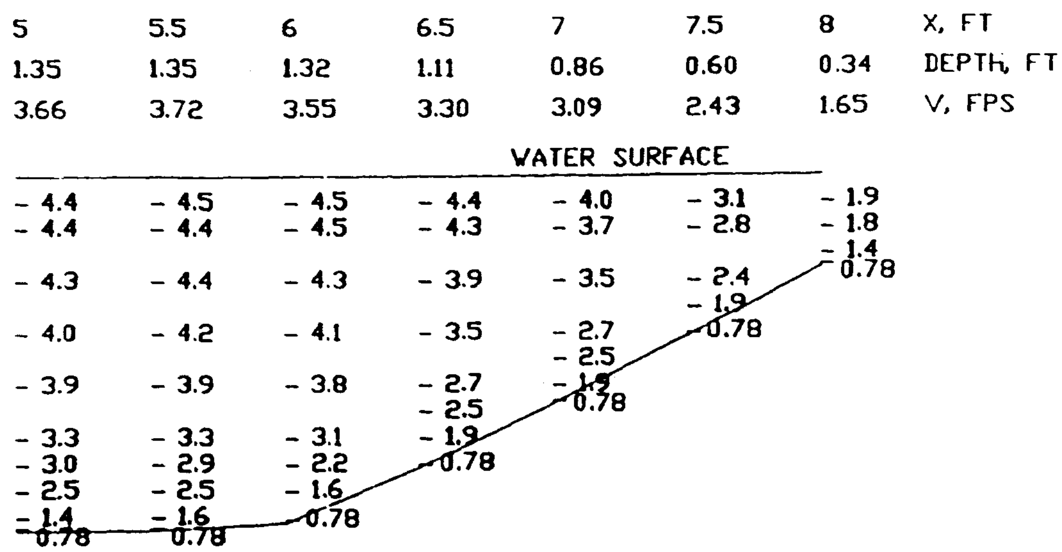
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.963

SIDE SLOPE VELOCITIES

TEST 502S602.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

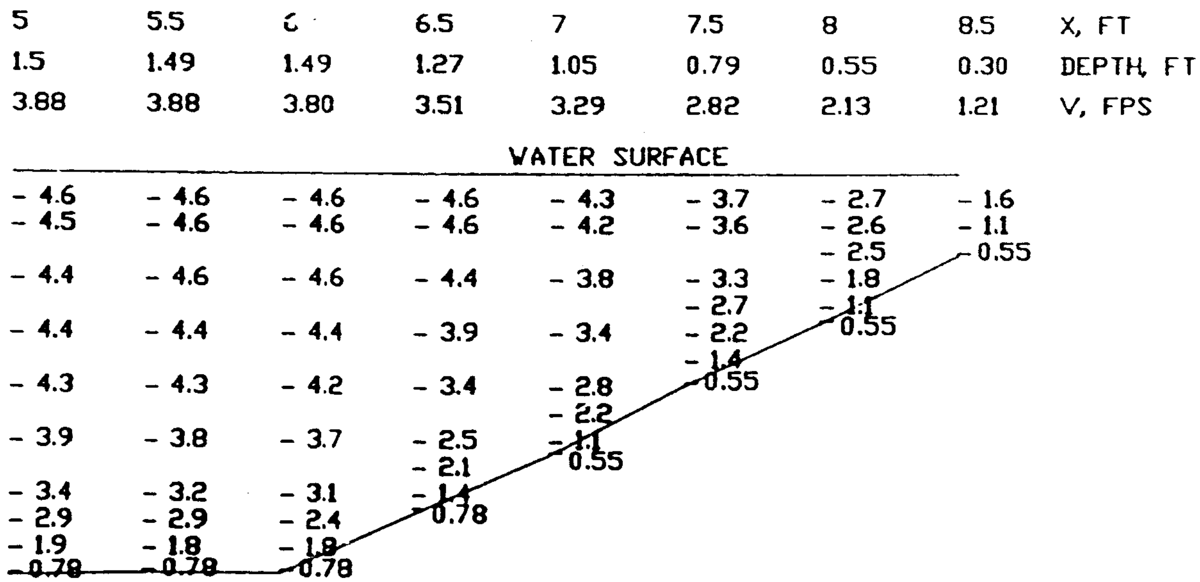
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.083

SIDE SLOPE VELOCITIES

TEST 602S602.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

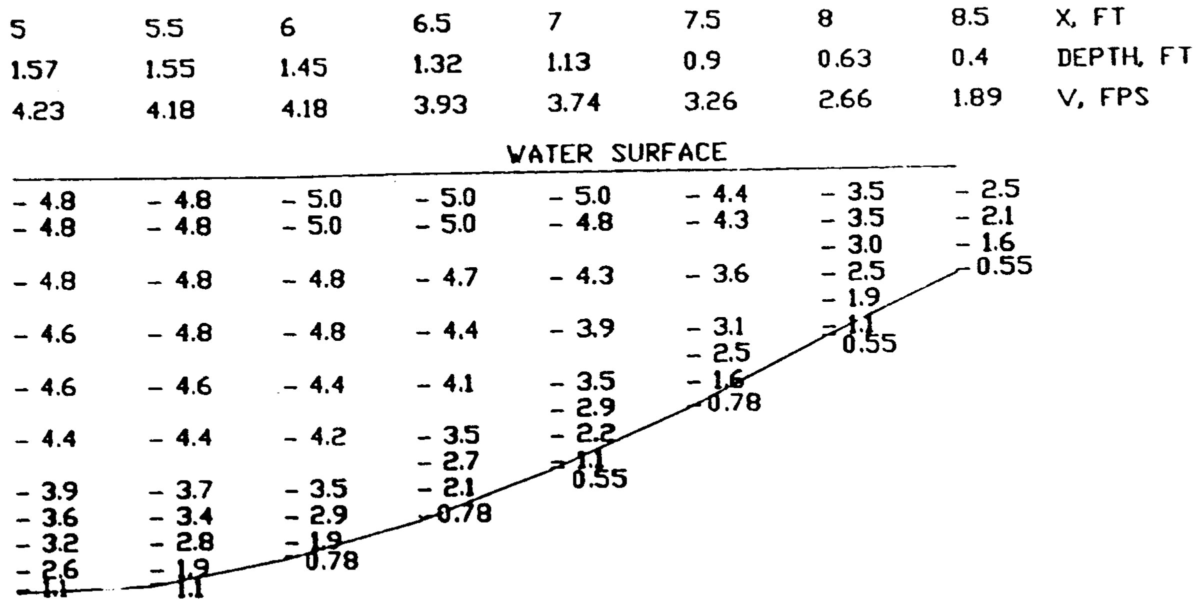
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.233

SIDE SLOPE VELOCITIES

TEST 702S602.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

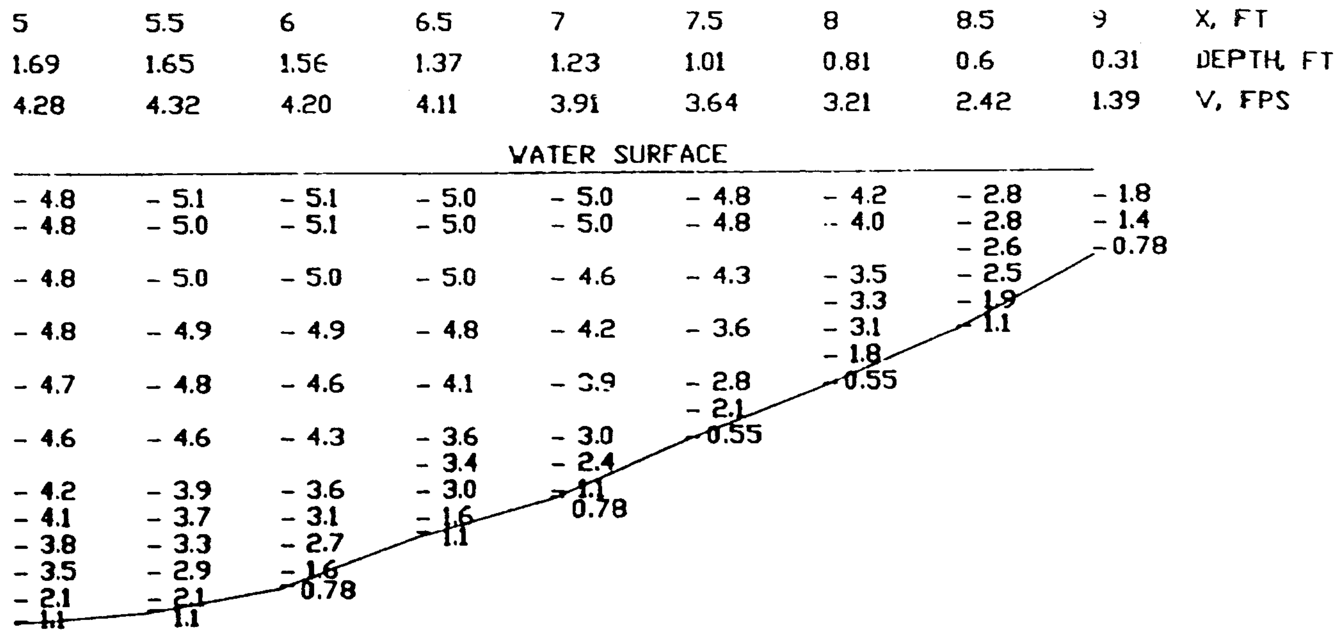
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.393

SIDE SLOPE VELOCITIES

TEST 802S602.GR9



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

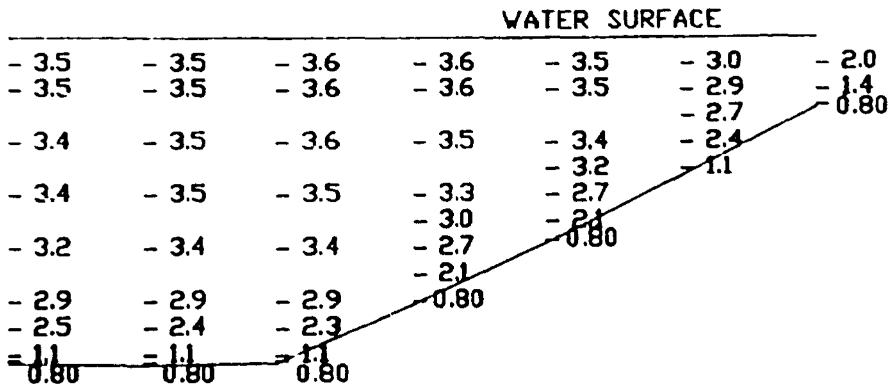
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.495

SIDE SLOPE VELOCITIES

TEST 902S602.GR9

5	5.5	6	6.5	7	7.5	8	X, FT
1.23	1.24	1.23	1.01	0.78	0.53	0.27	DEPTH, FT
3.10	3.13	3.18	3.06	3.02	2.48	1.60	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

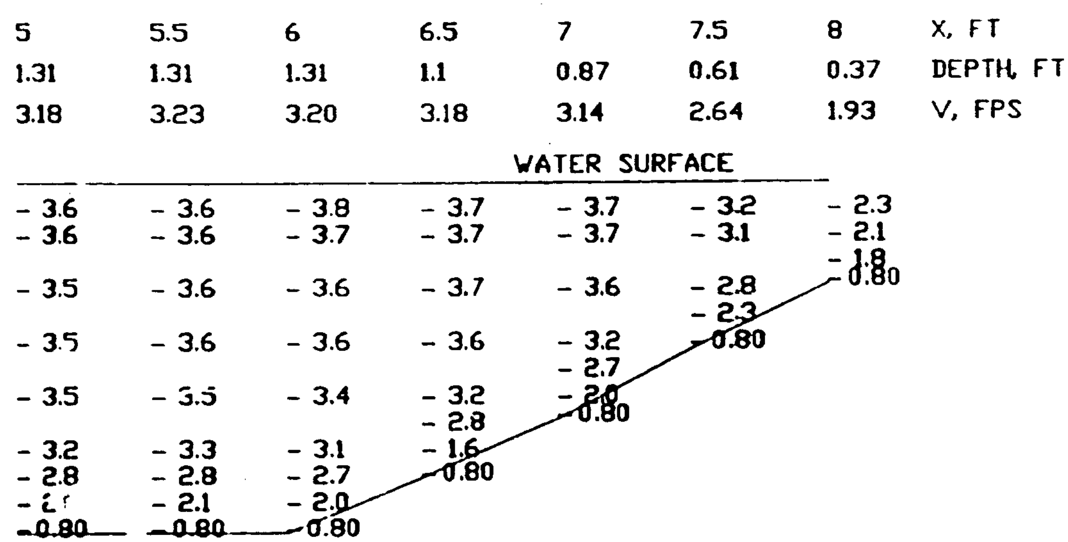
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.713

SIDE SLOPE VELOCITIES

TEST 402RS578.G10



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

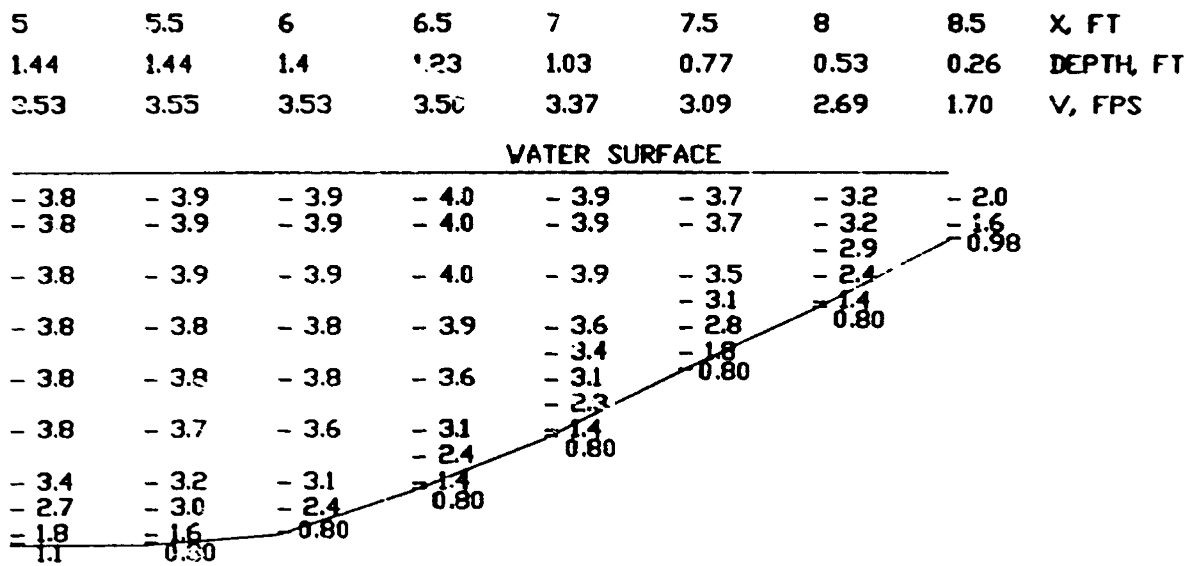
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.783

SIDE SLOPE VELOCITIES

TEST 452RS578.G10



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

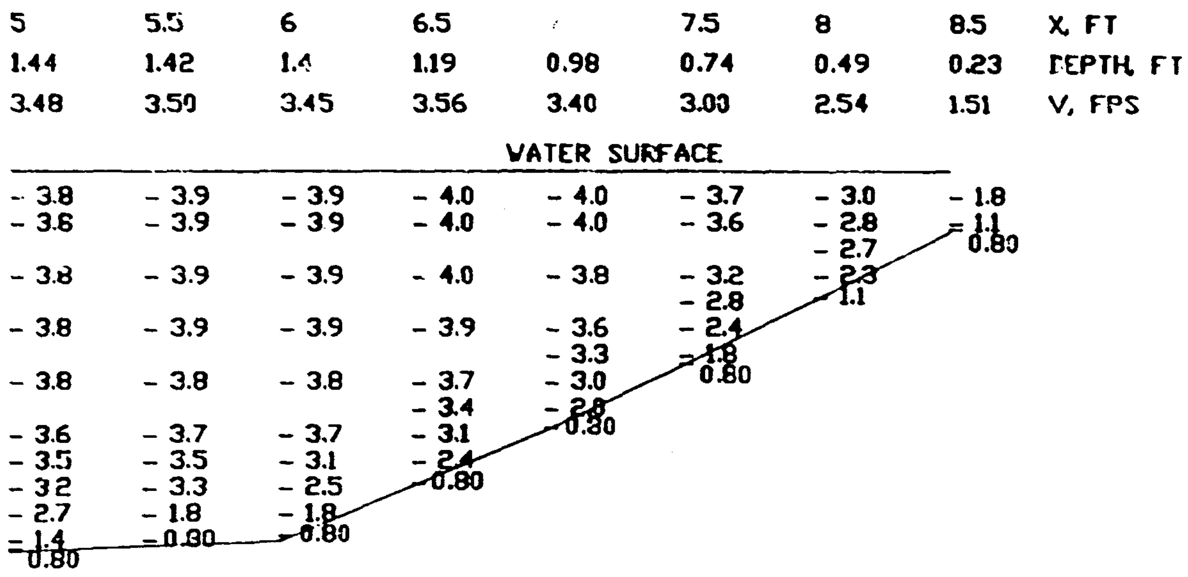
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.923

SIDE SLOPE VELOCITIES

TEST 502RS578.G10



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

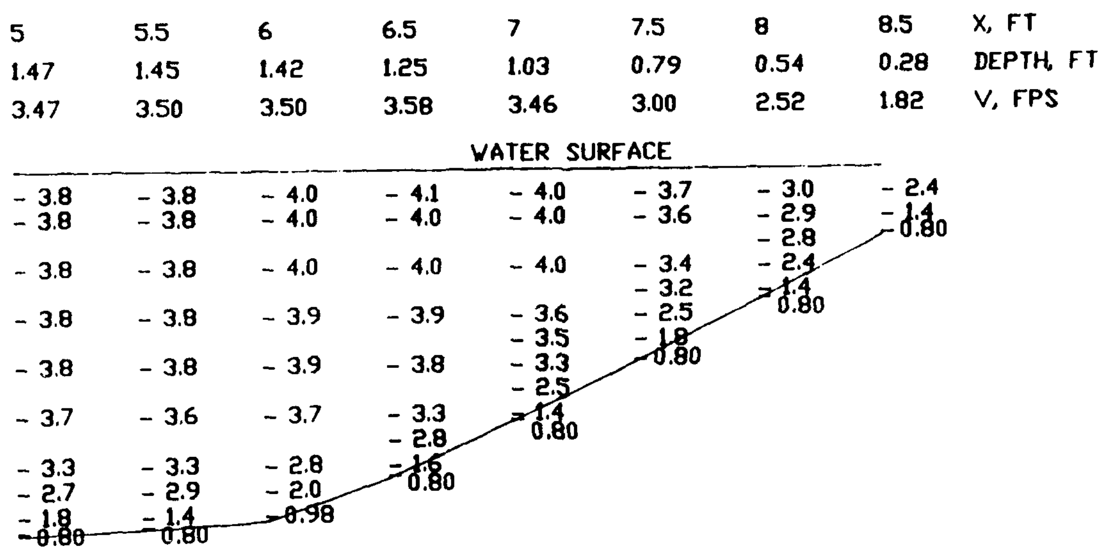
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.933

SIDE SLOPE VELOCITIES

TEST 502RS578.G11



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

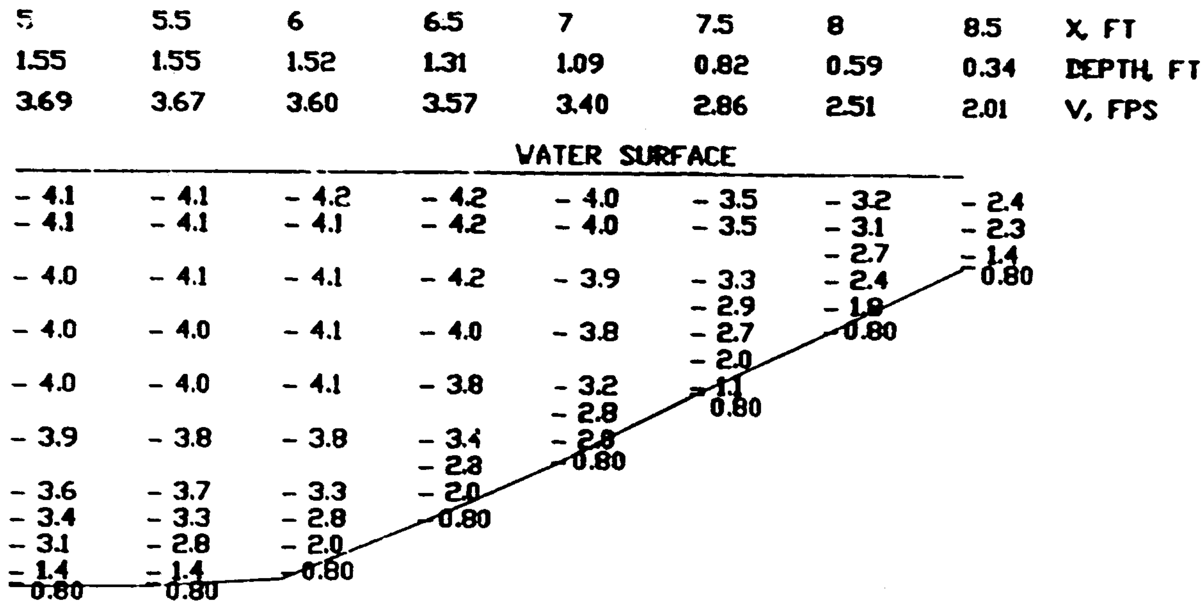
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.963

SIDE SLOPE VELOCITIES

TEST 552RS578.G11



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

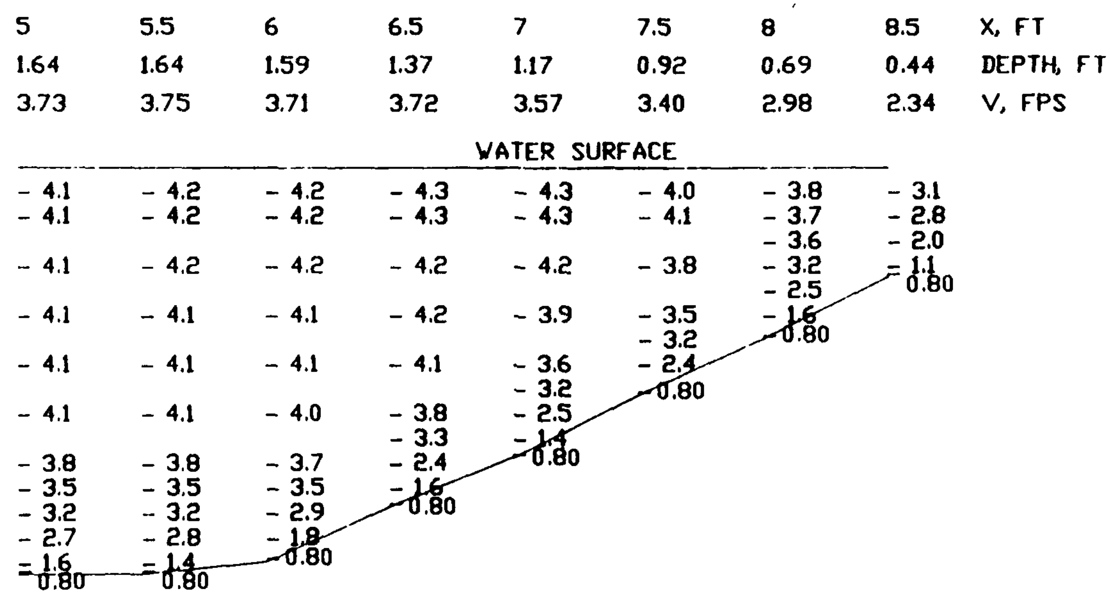
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.043

SIDE SLOPE VELOCITIES

TEST 602RS578.G11



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

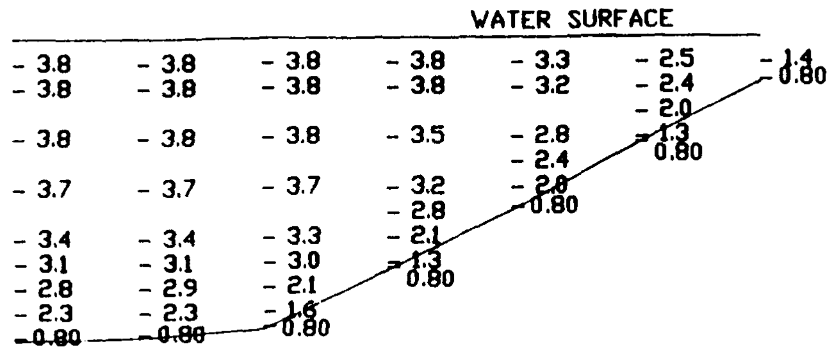
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.113

SIDE SLOPE VELOCITIES

TEST 652RS578.G11

5	5.5	6	6.5	7	7.5	8	X, FT
1.21	1.2	1.17	0.92	0.68	0.43	0.18	DEPTH, FT
3.29	3.31	3.26	3.10	2.67	2.10	1.22	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

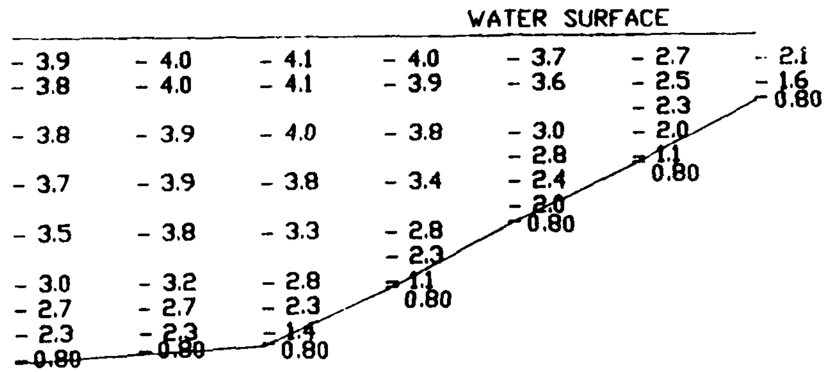
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.683

SIDE SLOPE VELOCITIES

TEST 402RS602.G10

5	5.5	6	6.5	7	7.5	8	X, FT
1.31	1.28	1.25	1.03	0.76	0.53	0.27	DEPTH, FT
3.32	3.50	3.37	3.26	2.91	2.18	1.75	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

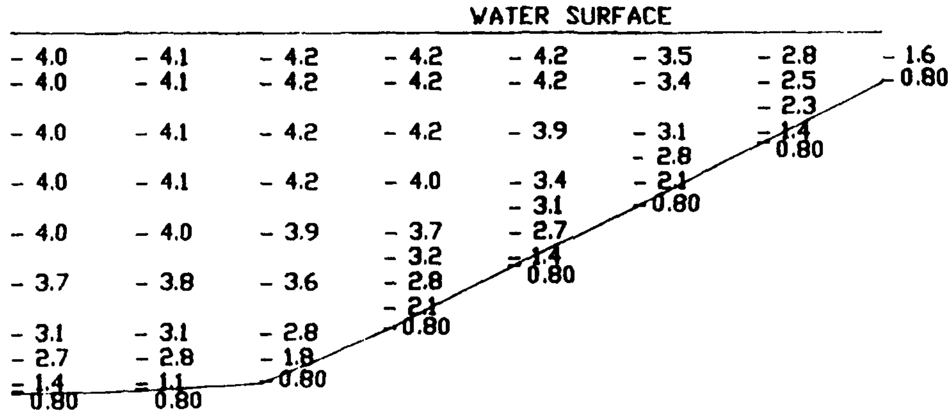
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.758

SIDE SLOPE VELOCITIES

TEST 452RS602.G10

5	5.5	6	6.5	7	7.5	8	8.5	X, FT
1.44	1.43	1.4	1.19	0.94	0.7	0.45	0.2	DEPTH, FT
3.59	3.66	3.63	3.60	3.43	2.88	2.25	1.36	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

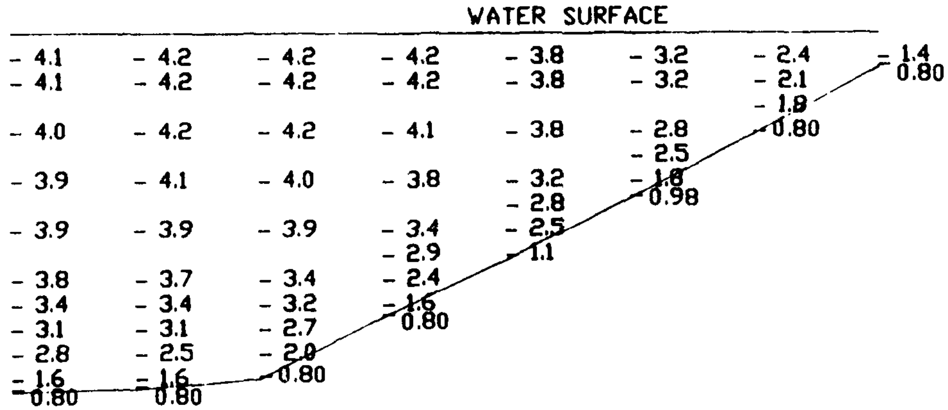
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.893

SIDE SLOPE VELOCITIES

TEST 502RS602.G10

5	5.5	6	6.5	7	7.5	8	8.5	X, FT
1.45	1.44	1.4	1.15	0.92	0.67	0.41	0.14	DEPTH, FT
3.60	3.66	3.58	3.50	3.24	2.70	1.94	1.25	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

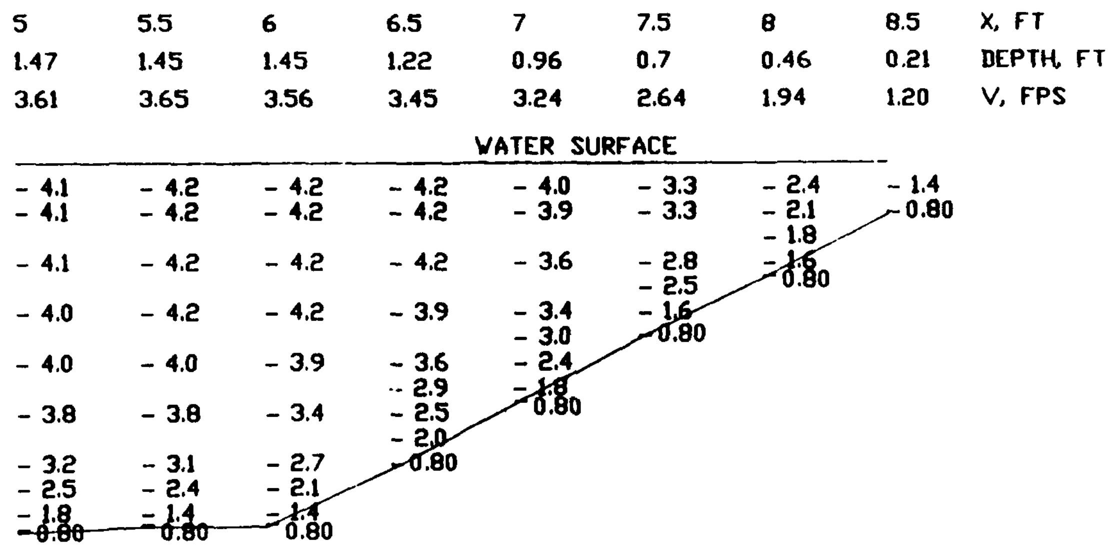
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.873

SIDE SLOPE VELOCITIES

TEST 502RS602.G11



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.903

SIDE SLOPE VELOCITIES

TEST 552RS602.G11

5	5.5	6	6.5	7	7.5	8	8.5	X, FT
1.55	1.54	1.53	1.3	1.06	0.8	0.54	0.29	DEPTH, FT
3.68	3.82	3.65	3.58	3.37	2.85	2.21	1.57	V, FPS

WATER SURFACE

- 4.1	- 4.3	- 4.4	- 4.4	- 4.1	- 3.5	- 2.8	- 2.0
- 4.1	- 4.2	- 4.4	- 4.3	- 4.1	- 3.5	- 2.7	- 1.4
- 4.1	- 4.2	- 4.4	- 4.3	- 3.8	- 3.3	- 2.3	- 0.80
- 4.2	- 4.2	- 4.3	- 4.1	- 3.6	- 2.8	- 1.8	
- 4.2	- 4.2	- 4.0	- 3.7	- 3.2	- 2.5	- 1.4	
- 4.1	- 4.1	- 3.6	- 3.0	- 2.9	- 1.8	- 0.80	
- 3.5	- 3.7	- 3.2	- 2.7	- 2.7	- 0.80		
- 3.1	- 3.1	- 2.7	- 2.0	- 2.0			
- 2.7	- 2.5	- 1.8	- 0.80	- 0.80			
- 0.80	- 1.6	- 1.1					
- 0.80	- 0.80	0.80					

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

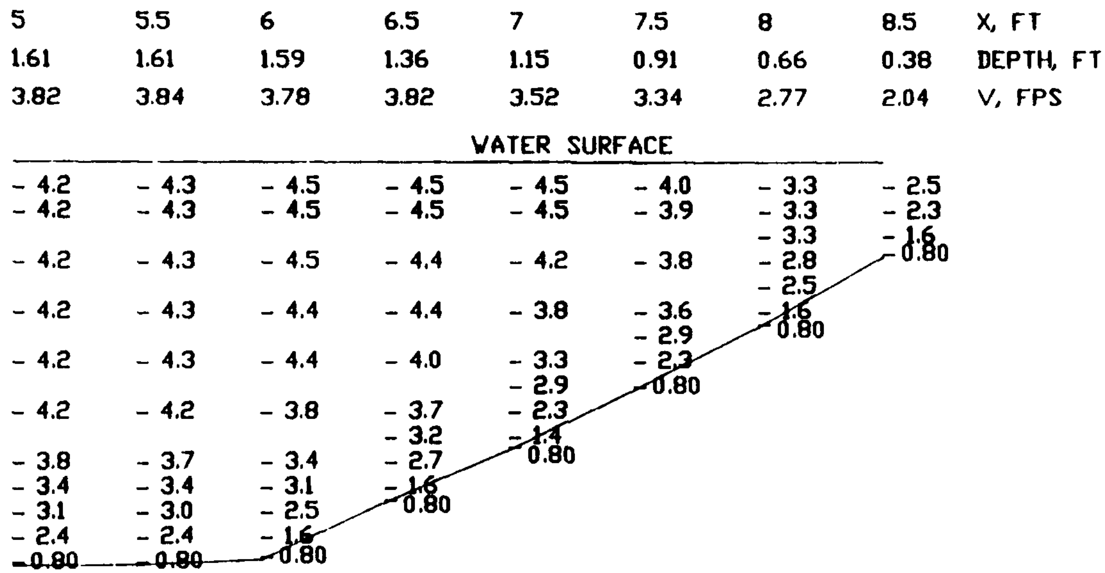
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.983

SIDE SLOPE VELOCITIES

TEST 602RS602.G11



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

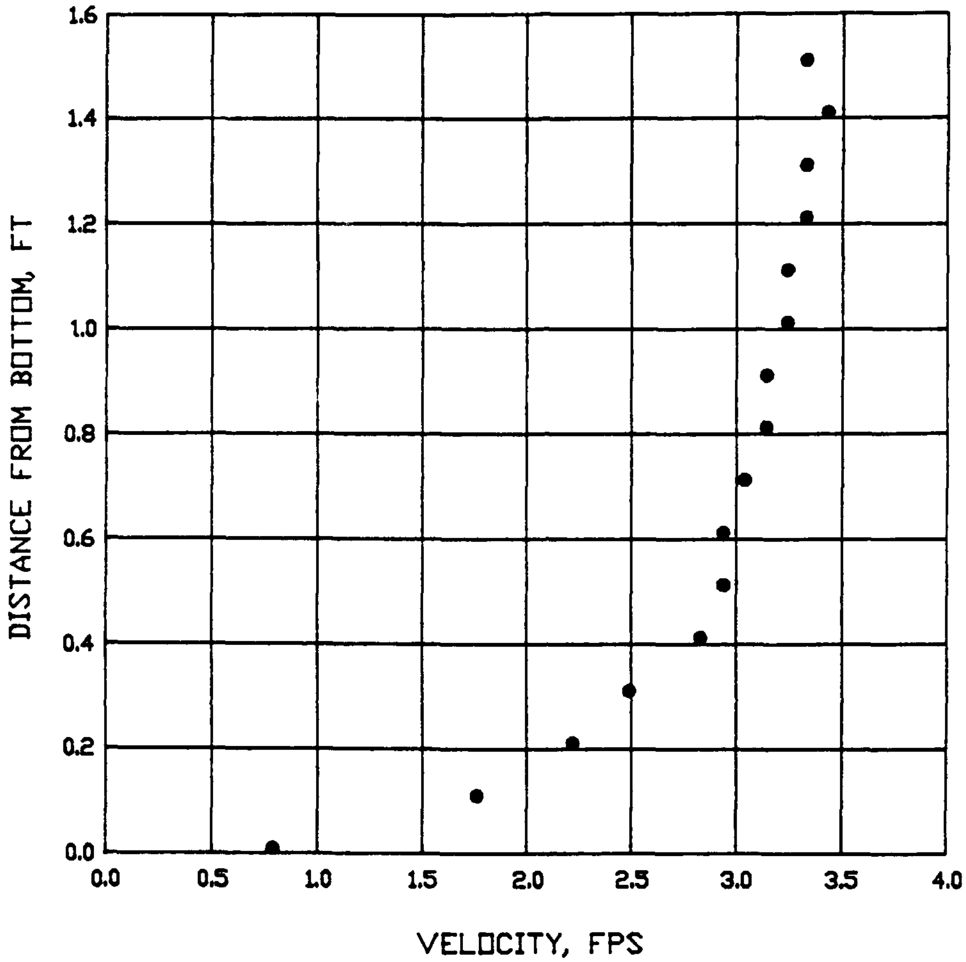
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.043

SIDE SLOPE VELOCITIES

TEST 652RS602.G11



DEPTH = 1.62 FT

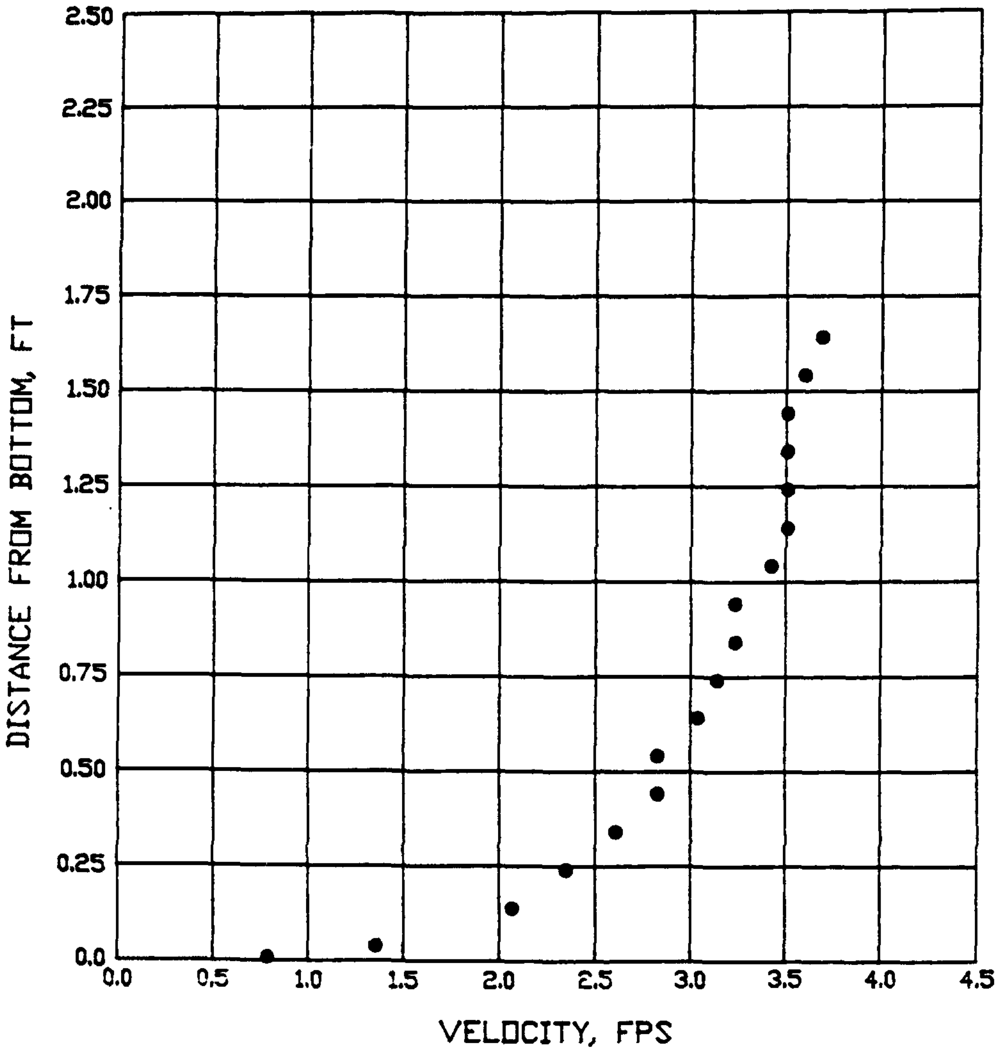
GRADATION NO. 6

STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

60 CFS



DEPTH = 1.75 FT

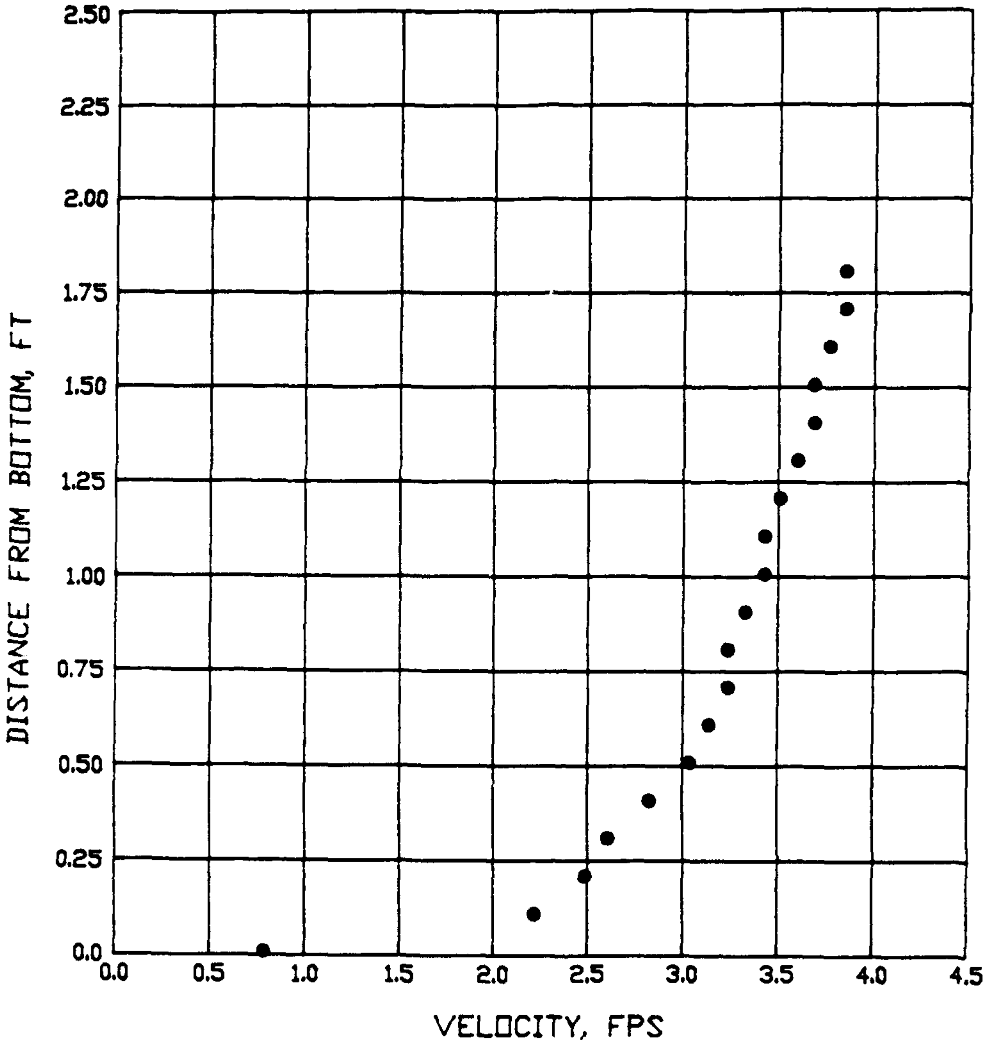
GRADATION NO. 6

STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

70 CFS



DEPTH = 1.92 FT

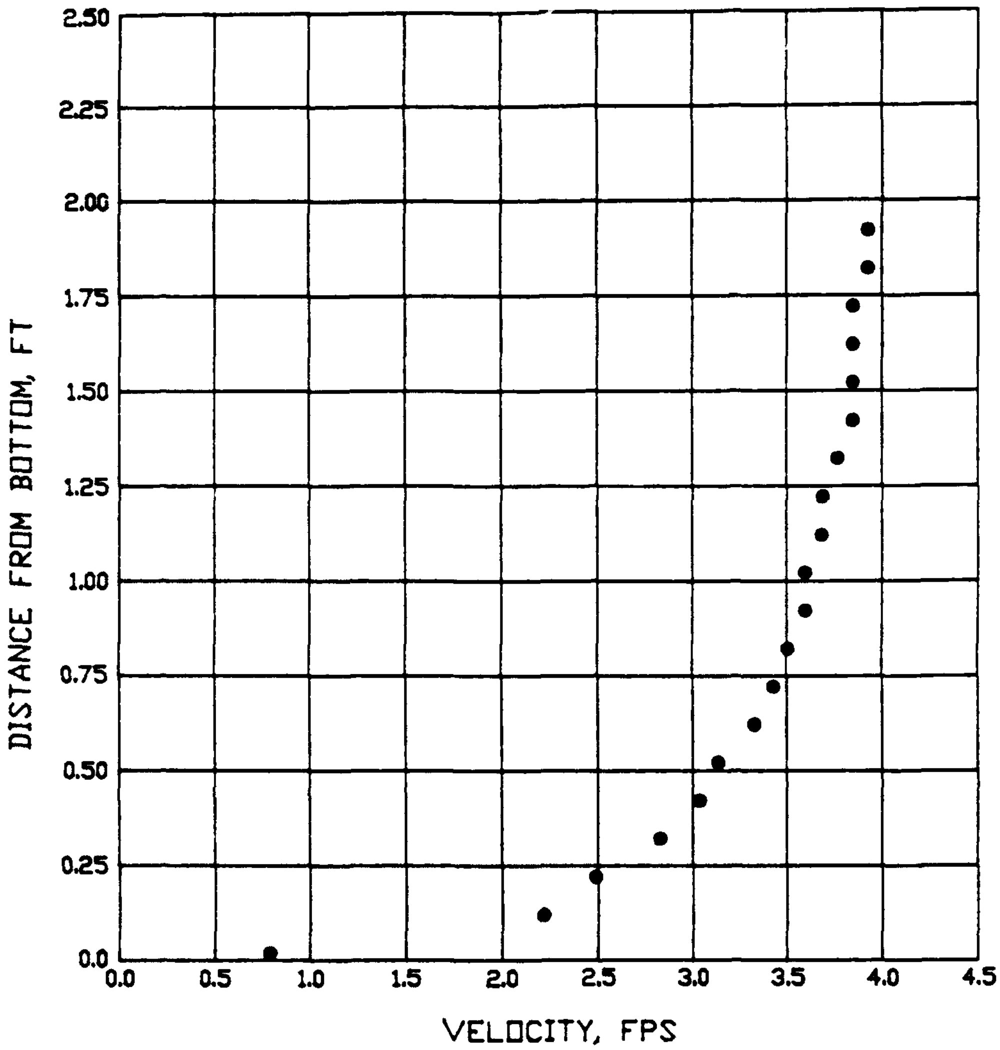
GRADATION NO. 6

STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

80 CFS



DEPTH = 2.03 FT

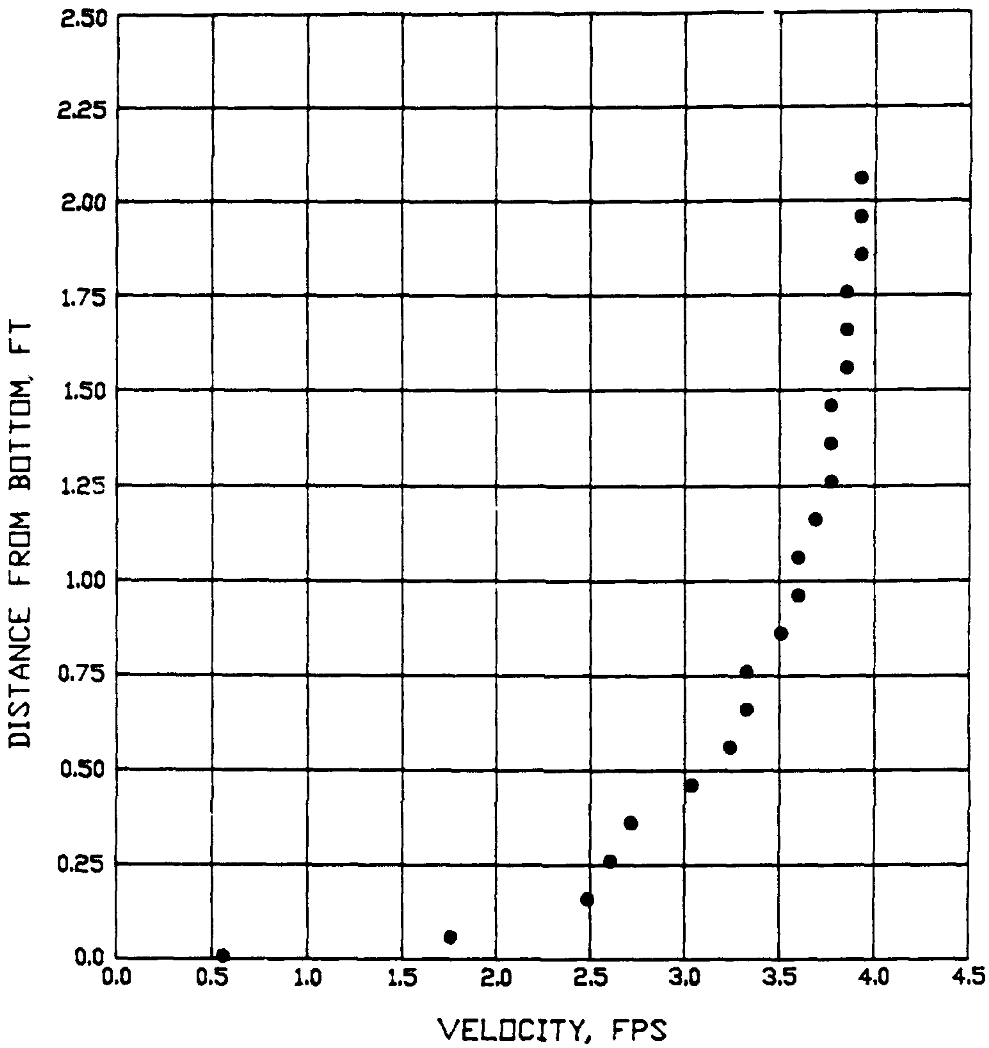
GRADATION NO. 6

STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

90 CFS



DEPTH = 2.17 FT

GRADATION NO. 6

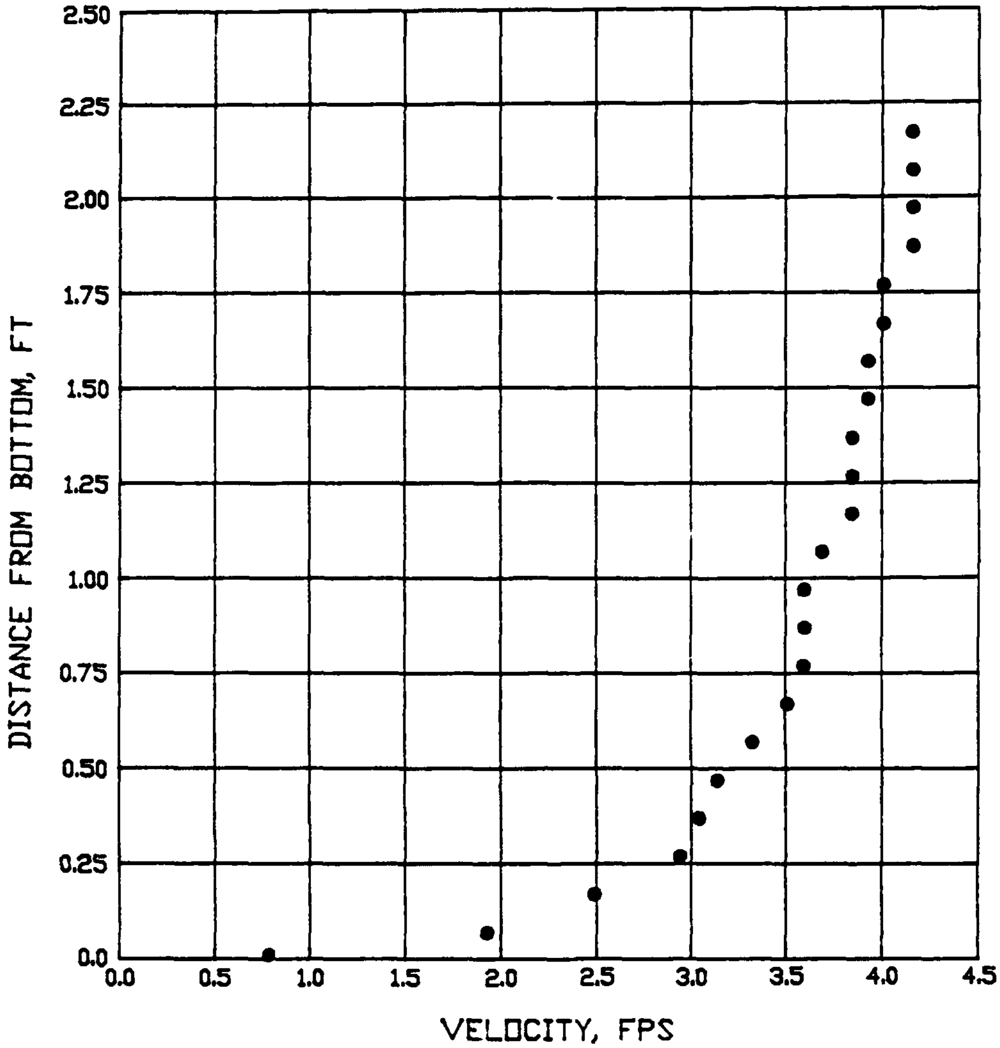
STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

100 CFS

PLATE A141



DEPTH = 2.28 FT

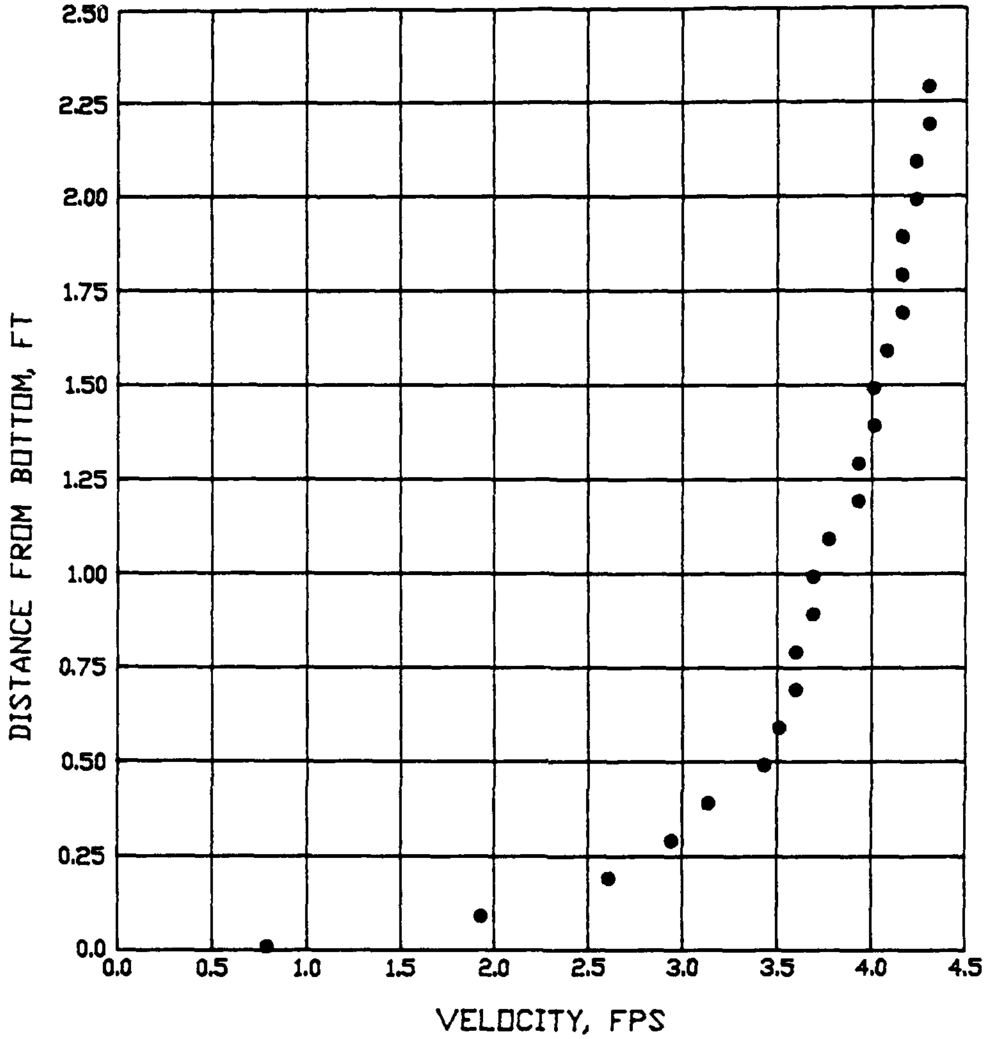
GRADATION NO. 6

STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

110 CFS



DEPTH = 2.39 FT

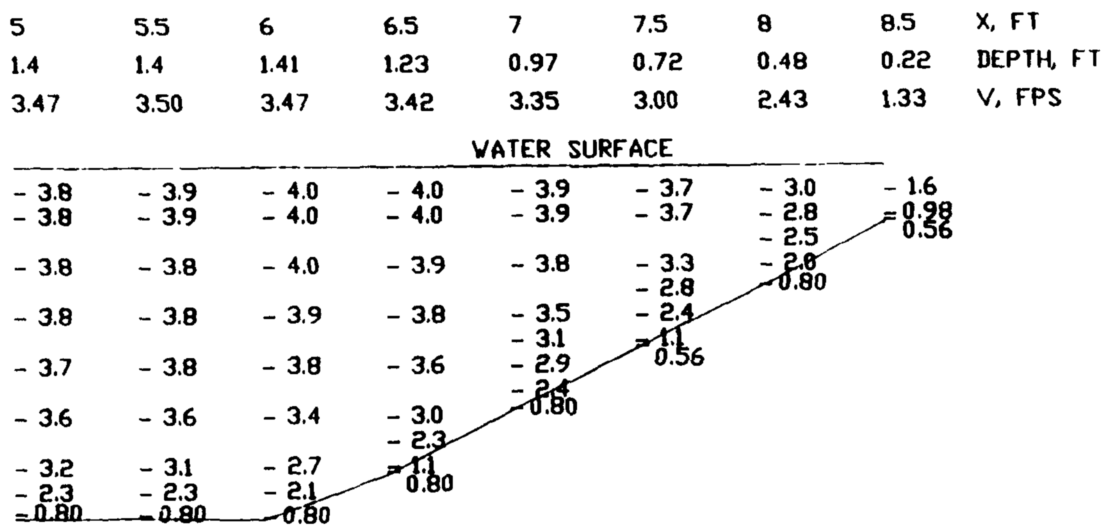
GRADATION NO. 6

STATION 1+63

VELOCITY PROFILE

BOTTOM RIPRAP

120 CFS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

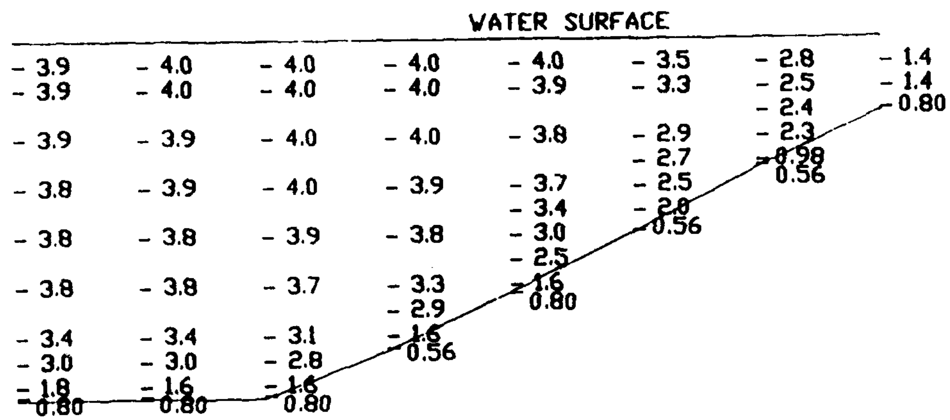
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.018

SIDE SLOPE VELOCITIES

TEST 552SG578.GR2

5	5.5	6	6.5	7	7.5	8	8.5	X, FT
1.45	1.45	1.45	1.26	1.03	0.79	0.53	0.3	DEPTH, FT
3.59	3.61	3.58	3.55	3.41	2.75	2.27	1.26	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

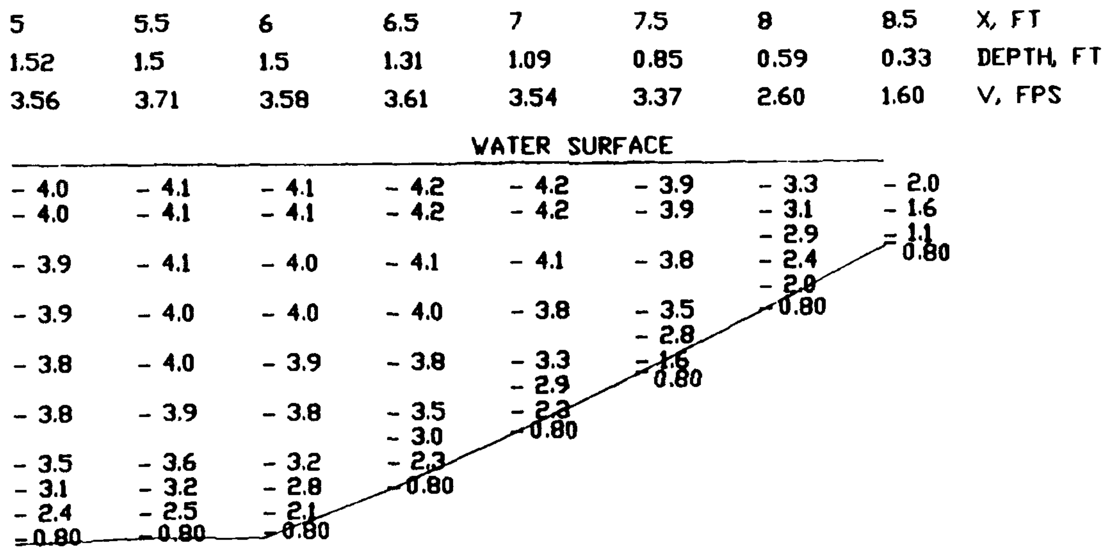
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.088

SIDE SLOPE VELOCITIES

TEST 602SG578.GR2



<u>LEGEND</u>

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.098

SIDE SLOPE VELOCITIES

TEST 652SG578.GR2

5	5.5	6	6.5	7	7.5	8	8.5	X, FT
1.61	1.63	1.61	1.41	1.19	0.93	0.67	0.41	DEPTH, FT
3.76	3.87	3.82	3.61	3.39	3.28	2.77	2.28	V, FPS

WATER SURFACE

- 4.2 - 4.2 - 4.2 - 4.2 - 4.1 - 4.0 - 3.8 - 3.2 - 2.5 - 0.80	- 4.2 - 4.2 - 4.2 - 4.2 - 4.2 - 4.1 - 3.9 - 3.5 - 2.7 - 1.4 0.80	- 4.3 - 4.3 - 4.2 - 4.2 - 4.2 - 4.1 - 3.8 - 3.1 - 2.7 - 0.56	- 4.2 - 4.2 - 4.2 - 4.2 - 4.0 - 3.5 - 3.2 - 2.9 - 1.6 - 0.80	- 4.1 - 4.1 - 4.0 - 3.8 - 3.3 - 3.1 - 2.5 - 2.8 - 0.80	- 3.8 - 3.8 - 3.8 - 3.5 - 2.9 - 2.5 - 1.4 0.80	- 3.4 - 3.3 - 2.8 - 2.5 - 2.1 - 0.80	- 2.8 - 2.7 - 2.3 - 0.80

LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

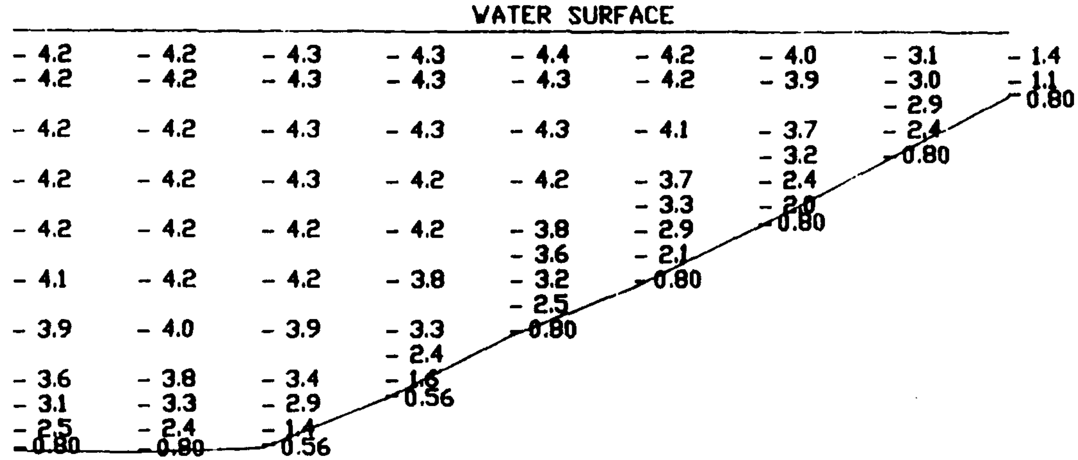
- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.173

SIDE SLOPE VELOCITIES

TEST 702SG578.GR2

5	5.5	6	6.5	7	7.5	8	8.5	9	X, FT
1.68	1.69	1.67	1.47	1.22	1.02	0.78	0.52	0.26	DEPTH, FT
3.83	3.92	3.85	3.72	3.75	3.45	3.20	2.58	1.22	V, FPS



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

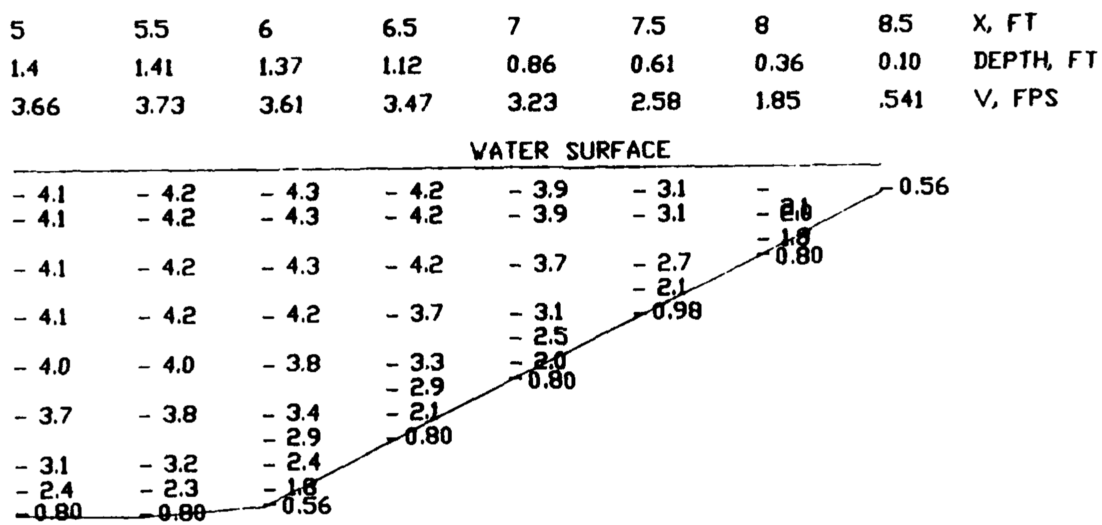
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.243

SIDE SLOPE VELOCITIES

TEST 752SG578.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

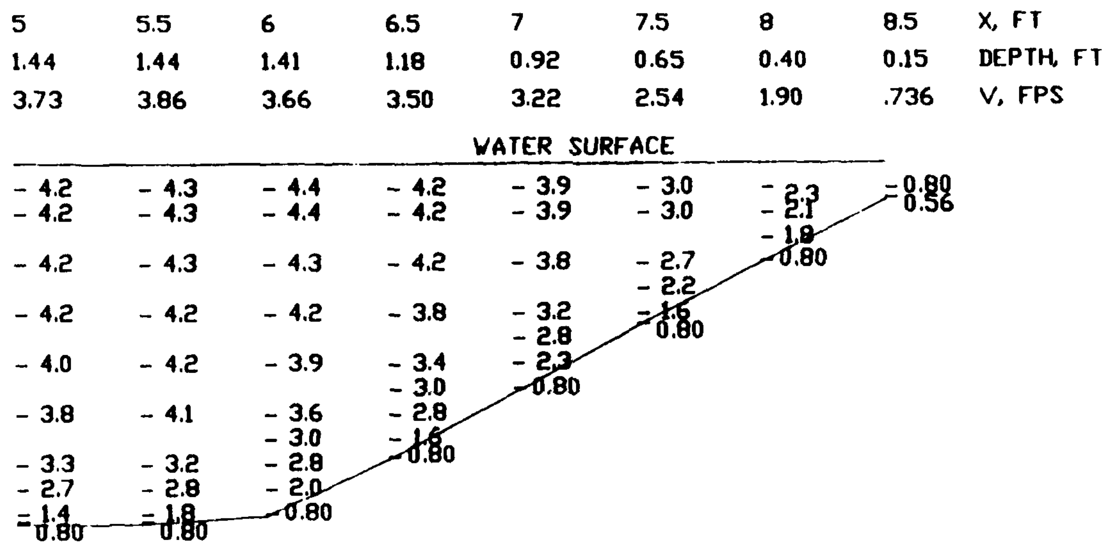
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 179.963

SIDE SLOPE VELOCITIES

TEST 552SG602.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

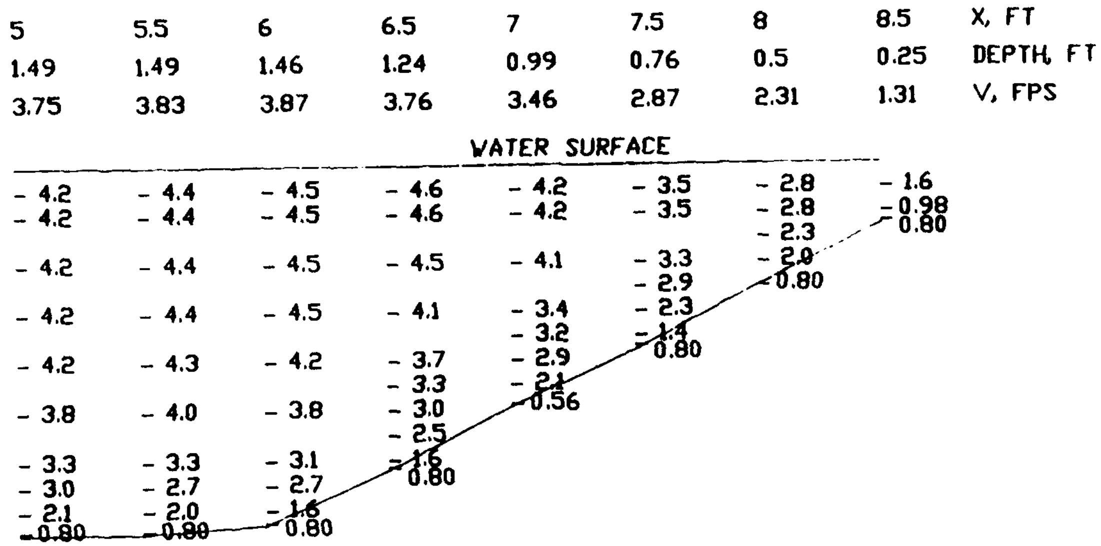
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.028

SIDE SLOPE VELOCITIES

TEST 602SG602.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

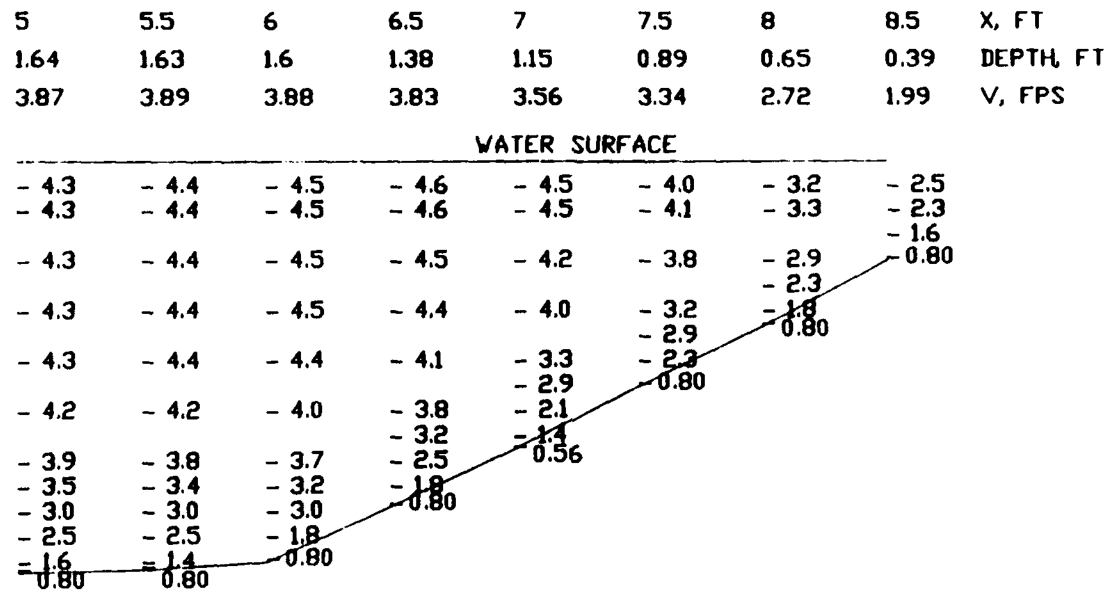
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.063

SIDE SLOPE VELOCITIES

TEST 652SG602.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

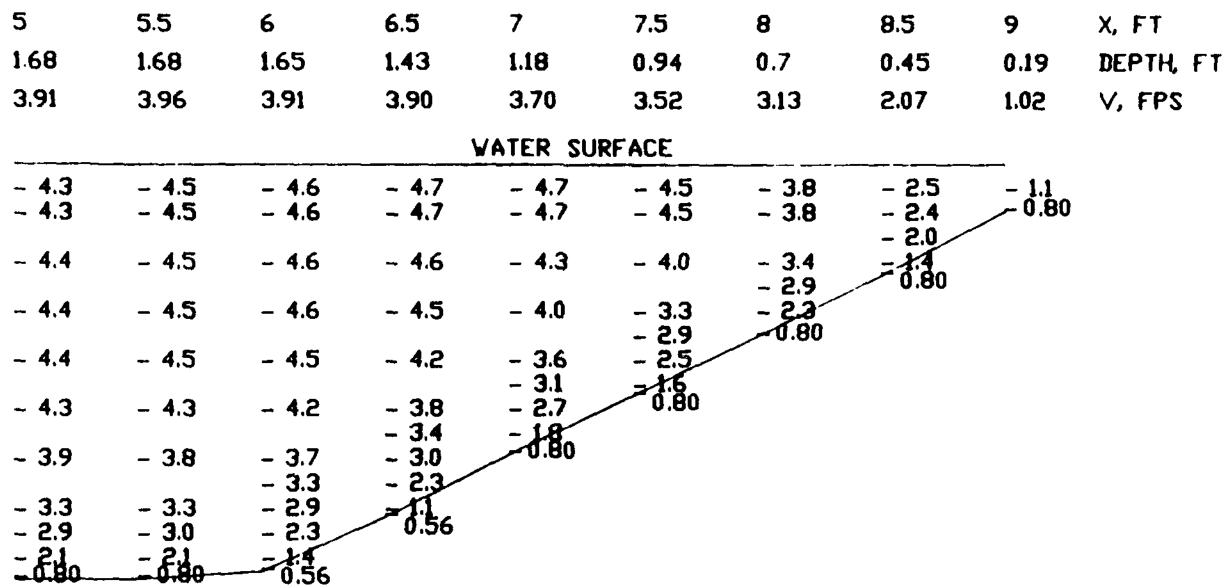
V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.153

SIDE SLOPE VELOCITIES

TEST 702SG602.GR2



LEGEND

X = DISTANCE FROM CHANNEL CENTER LINE, FT

V = DEPTH-AVERAGED VELOCITY, FPS

- 3.3 POINT VELOCITY OVER SIDE SLOPE, FPS

NOTE: WATER-SURFACE ELEVATION AT CHANNEL CENTER LINE = 180.213

SIDE SLOPE VELOCITIES

TEST 752SG602.GR2

APPENDIX B: DESCRIPTION OF ROCK MOVEMENT AND FAILURE

Table B1

1V:2H Stability Test Results

Test No.	Gradation No.	Curve No.	Detailed Test Results
11R1	2	3	Stable, very little movement.
11R2	2	3	Stable, some movement in red and yellow zones.
11R3	2	3	Stable, some movement in red and yellow zones.
12R1	2	3	Stable, very little movement.
12R2	2	3	Stable, some movement in red and yellow zones.
12R3	2	3	Stable, some movement in red and yellow zones. Weak areas in red and yellow zones starting to show.
12R4	2	3	Stable, some movement in red and yellow zones. Weak areas in red and yellow zones showing up.
13R1	2	3	Stable, some movement in red and yellow zones.
13R2	2	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 583, major (above 4 in.).
13R3	2	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 578, major (above 4 in.).
1R1	2	1	Stable, very little movement.
1R2	2	1	Stable, some movement in red and yellow zones. Weak areas in yellow zone showing up.
1R3	2	1	Stable, some movement in red and yellow zones. Weak areas in red and yellow zones showing up.
2R1	2	1	Failure, some movement in red and yellow zones. Yellow zone, sta 300, 325, major (above 4 in.). Sta 245, 248, 255, 260, 275, 295, minor (0-4 in.). Red zone, sta 254, 317, minor (0-4 in.).
14R1	2	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 583, 602, major (above 4 in.).
14R2	2	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 578, major (above 4 in.).

(Continued)

(Sheet 1 of 7)

Table B1 (Continued)

Test No.	Gradation No.	Curve No.	Detailed Test Results
3R1	2	1	Failure, lots of movement in red and yellow zones. Some in black zone. Yellow zone, sta 294, 298, major (above 4 in.). Sta 245, 267, 283, 290, 303, minor (below 4 in.). Red zone, 259, 267, minor (below 4 in.).
3R2	2	1	Failure, lots of movement in red and yellow zones. Yellow zone, sta 284, major (above 4 in.). Sta 254, 288, 298, 308, 317, minor (below 4 in.). Red zone, sta 287, 295, minor (below 4 in.).
4R1	2	1	Failure, lots of movement in red and yellow zones. Some movement in black zone. Yellow zone, sta 258, major (above 4 in.). Sta 244, 246, 268, 282, 289, 294, minor (below 4 in.). Red zone, 253, 310, minor (below 4 in.).
4R2	2	1	Failure, lots of movement in red and yellow zones. Some movement in black zone. Yellow zone, sta 255, 283, 293, 295, 302, major (above 4 in.). Sta 234, 237, 243, 248, 258, 275, 289, 308, 313, minor (below 4 in.). Red zone, sta 237, 253, 256, 281, 286, 292, minor (below 4 in.).
5R1	2	1	Failure, lots of movement in red and yellow zones. Some movement in black zone. Yellow zone, sta 245, 255, 268, 280, major (above 4 in.). Sta 247, 248, 259, 260, 263, 275, 290, 308, 311, 320, 330, minor (below 4 in.). Red zone, sta 240, 242, 253, 309, minor (below 4 in.).
20R1	3	3	Stable, very little movement.
21R1	3	3	Stable, some movement in red and yellow zones.
21R2	3	3	Stable, some movement in red and yellow zones.
22R1	3	3	Stable, some movement in red and yellow zones.
22R2	3	3	Stable, some movement in red and yellow zones.
22R3	3	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 550, 568, 583, and 584, major (above 4 in.). Sta 570, 575, 610, minor (below 4 in.). Red zone, sta 550, 610, 623, major (above 4 in.). Sta 555, 578, 587, minor

(Continued)

(Sheet 2 of 7)

Table B1 (Continued)

Test No.	Grada-tion No.	Curve No.	Detailed Test Results
22R3 (Cont.)			(below 4 in.). Sta 555, 578, 587, minor (below 4 in.).
6R1	3	1	Stable, very little movement.
23R1	3	3	Failure, lots of movement in yellow zone. Some movement in red zone. Yellow zone, sta 573, 583, major (above 4 in.).
23R2	3	3	Failure, some movement in red and yellow zones. Yellow zone, sta 565, 585, major (above 4 in.). Sta 595, minor (below 4 in.). Red zone, sta 552, 555, 615, minor (below 4 in.).
7R1	3	1	Failure, lots of movement in red and yellow zones. Very little in black. Yellow zone, sta 252, 315, 320, major (above 4 in.). Red zone, sta 257, major (above 4 in.). Sta 225, 252, 270, minor (below 4 in.).
8R1	3	1	Stable, very little movement.
24R1	3	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 565, 585, 595, major (above 4 in.). Red zone, sta 252, 315, 320, minor (below 4 in.).
28R1	4	3	Stable, very little movement.
29R1	4	3	Stable, very little movement.
30R1	4	3	Stable, some movement in red and yellow zones.
30R2	4	3	Failure, lots of movement between sta 570 and 590 in red and yellow zones. Very little in rest of test section. Yellow zone, sta 580, 583, major (above 4 in.). Red zone, sta 583, major (above 4 in.).
30R3	4	3	Stable, some movement between sta 585 and 625 in red and yellow zones. Very little in rest of test section.
30R4	4	3	Stable, some movement in red and yellow zones.
31R1	4	3	Stable, significant movement in red and yellow zones.
			Some movement in lower half of black zone.
31R2	4	3	Stable, some movement in red and yellow zones, and lower half of black zone.

(Continued)

(Sheet 3 of 7)

Table B1 (Continued)

Test No.	Gradation No.	Curve No.	Detailed Test Results
31R3	4	3	Failure, lots of movement in red and yellow zones and lower half of black zone. Yellow zone, sta 585, major (above 4 in.). Black zone, sta 580, major (above 4 in.).
32R1	4	3	Failure, lots of movement in red and yellow zones and lower half of black zone. Sta 585, major (above 4 in.), covering upper half of red zone, yellow zone, and lower half of black zone.
34R1	4	3	Failure, lots of movement in red and yellow zones and lower half of black zone. Yellow zone, sta 582, 585, major (above 4 in.). Black zone, sta 585, major (above 4 in.). Failure occurred approximately 21 hr into test.
35R1	5	3	Failure, lots of movement. Riprap was not painted. Failures occurred approximately 1.5 to 2 ft from toe of slope. Failures started occurring 22 hr into test. Failure points: sta 562, 567, 584, 588, 592, 596, 612, and 618, major (above 4 in.).
36R1	5	3	Stable, some movement in red zone and lower half of yellow zone.
37R1	5	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 570, 582, 585, major (above 4 in.).
38R1	6	3	Stable, very little movement in red and yellow zones.
39R1	6	3	Failure, lots of movement in red zone and lower half of yellow zone. Yellow zone, sta 580, 594, major (above 4 in.). Red zone, sta 615, major (above 4 in.). Sta 550, 93, minor (below 4 in.).
40R1	7	3	Stable, some movement in red and yellow zones.
41R1	7	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 580, major (above 4 in.).
42R1	7	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 580, 584, major (above 4 in.). Failure was discovered 41 hr into test.

(Continued)

(Sheet 4 of 7)

Table B1 (Continued)

Test No.	Grada-tion No.	Curve No.	Detailed Test Results
43R1	8	3	Stable, some movement in red and yellow zones.
44R1	8	3	Stable, lots of movement in red and yellow zones.
44R2	8	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 583, major (above 4 in.).
45R1	8	3	Failure, lots of movement in red and yellow zones. Yellow zone, sta 584, 581, major (above 4 in.). Failure occurred 29 hr into test.
46R1	9	3	Stable, some movement in red and yellow zones.
47R1	9	3	Stable, lots of movement in red and yellow zones. Some weak areas, but no holes where filter cloth could be seen.
48R1	9	3	Stable, large amount of movement in red and yellow zones. Some weak areas, but no holes where filter cloth could be seen.
48R2	9	3	Stable, lots of movement over entire length of test section. Some weak areas, but no holes where filter cloth could be seen. Riprap was not painted before test was started.
49R1	9	3	Stable, large amount of movement in red and yellow zones, and lower third of black zone. Some weak areas, but no holes where filter cloth could be seen.
49R2	9	3	Stable, large amount of movement over entire length of test section. Some weak areas, but no holes where filter cloth could be seen. Riprap was not painted before test was started.
50R1	9	3	Failure, large amount of movement in red and yellow zones and lower half of black zone. Black zone, sta 585-586, major (above 4 in.).
50R2	9	3	Failure, large amount of movement over entire length of test section. Failure points: sta 584 and 592, major (above 4 in.). Failure points were located approximately 4 ft from toe of slope. Riprap was not painted before test was started.

(Continued)

(Sheet 5 of 7)

Table B1 (Continued)

Test No.	Gradation No.	Curve No.	Detailed Test Results
51R1*	10	3	Failure, light to moderate amount of movement sta 538 to 562 and sta 595 to 625 in red and yellow zones. Lots of movement sta 562 to 595 in red and yellow zones. Highest area of movement with failure is sta 575 to 590. Failure points: yellow zone, sta 584 and 586, major (above 4 in.).
51R2*	10	3	Failure, very little movement sta 538 to 560 in red and yellow zones. Light to moderate amount of movement sta 560 to 570 in red and yellow zones. Lots of movement sta 570 to 590 in red and yellow zones. Some movement in red and yellow zones, sta 590 to 625. Highest area of movement with failures and major weak area is sta 575 to 590 in red and yellow zones. Failure points: yellow zone, sta 573, 582, and 583, major (above 4 in.); red zone, sta 581, 583, 601, and 616, major (above 4 in.).
52R2*	10	3	Stable, very little movement sta 538 to 570 in red and yellow zones. Light to moderate amount of movement sta 570 to 625 in red and yellow zones. Highest area of movement with one small hole in red zone at sta 280 (less than 2 in.), sta 575 to 590.
53R1*	10	3	Failure, very little movement sta 538 to 560 in red and yellow zones. Lots of movement sta 560 to 600 in red and yellow zones. Some movement sta 600 to 625 in red and yellow zones. Highest area of movement with failure, sta 573 to 588 in red and yellow zones. Failure points: yellow zone, sta 574, 579, 583, and 584, major (above 4 in.). Red zone, sta 615, major (above 4 in.).
54R1	11	3	Stable, some movement in yellow zone sta 538 to 560; very little in red zone. Lots of movement, but no failures, sta 560 to 586 in yellow zone; some movement in red zone. Some movement sta 585 to 625 in red and yellow zones. Highest area of movement sta 570 to 585 in yellow zone.

(Continued)

* Rounded stone.

(Sheet 6 of 7)

Table B1 (Concluded)

Test No.	Gradation No.	Curve No.	Detailed Test Results
55R1*	11	3	Stable, some movement sta 538 to 560 in yellow zone; very little in red zone. Lots of movement sta 560 to 590 in yellow zone; some movement in red zone. Some movement sta 590 to 625 in red and yellow zones. Highest area of movement sta 570 to 590 in yellow zone. No holes of any size or major weak areas.
56R1*	11	3	Failure, some movement sta 538 to 565 in red and yellow zones. Lots of movement in yellow zone sta 565 to 590, some movement in red zone. Some movement sta 590 to 625 in red and yellow zones. Highest area of movement with failure points sta 570 to 590 in red and yellow zones. Failure points: yellow zone, sta 568, 576, and 580, major (above 4 in.); sta 585, 599, and 606, minor (below 4 in.); red zone, sta 548, 565, 581, and 597, minor (below 4 in.)
56R2*	11	3	Stable, not much movement sta 538 to 565 in red and yellow zones. Lots of movement sta 565 to 590 in yellow; some movement in red zone. Some movement sta 590 to 625 in red and yellow zones. Highest area of movement with weak areas, sta 570 to 585 in yellow zone. Major weak areas: yellow zone, sta 575, 580 to 585, and 595; red zone, sta 595.
57R1	11	3	Failure, some movement sta 538 to 555 in red and yellow zones; very little in black. Lots of movement in yellow zone sta 560 to 625; some movement in red zone; very little in black zone. Highest area of movement with three major failures is sta 570 to 595 in yellow zone. Failure points: yellow zone, sta 570, 574 to 575, 584, 586, major (above 4 in.); sta 560, 598, and 608, minor (below 4 in.). Note: all holes and failures are located in top third of yellow zone.

* Rounded stone.

(Sheet 7 of 7)

Table B2

1V:3H Stability Test Results

Test No.	Gradation No.	Curve No.	Detailed Test Results
1R1	6	1	Stable, very little movement.
2R1	6	1	Stable, some movement in red and yellow zones.
3R1	6	1	Stable, some movement in red, yellow, and lower half of black zones.
4R1	6	1	Stable, some movement in red, yellow, and black zones. Weak areas in red and yellow zones showing up.
4R2	6	1	Stable, some movement in red, yellow, and black zones. Weak areas in red and yellow zones showing up.
5R1	6	1	Stable, very little movement sta 222 to 250 in all three zones. Moderate amount of movement from sta 250 to 331 in red and yellow zones. Very little in black zone. Some weak areas in red and yellow zones showing up with small holes, less than 3 in.
5R2	6	1	Stable, very little movement sta 222 to 250 in all three zones. Some movement from sta 250 to sta 331 in red and yellow zones. Very little in black. Some weak areas in red and yellow zones showing up with small holes, less than 3 in.
6R1	6	1	Failure, very little movement sta 222 to 250 in all three zones. Lots of movement from sta 250 to 331 in red and yellow zones. Lesser amount in black zone. Failure points: red zone, sta 251, 274, 277, 282, 392, major (above 4 in.); yellow zone, sta 263, 274, 280, major (above 4 in.), sta 283, 308, minor (below 4 in.).
6R2	6	1	Failure, very little movement sta 222 to 250 in all three zones. Lots of movement from sta 250 to 331 in red and yellow zones, lesser amount in black zone. Highest area of movement with failure points is sta 260 to 290. Failure points: red zone, sta 262, 275, 277, 302, 315, major (above 4 in.), sta 235, 245, 272, 280, minor (below 4 in.); yellow zone, sta 250, 287, and 295, minor (below 4 in.).

(Continued)

(Sheet 1 of 6)

Table B2 (Continued)

Test No.	Grada-tion No.	Curve No.	Detailed Test Results
6R3	6	1	Stable, very little movement sta 222 to 245 in red, yellow, and black zones. Sta 245 to 331, some movement in red and yellow zones, very little in black zone. Highest area of movement sta 270 to 300 in red and yellow zones with weak areas showing up and two small holes, less than 2 in. at 280 in red zone and sta 281 in yellow zone.
7R1	6	1	Failure, very little movement sta 222 to 230 in red, yellow, and black zones. Sta 230 to 260, some movement in red and yellow zones. Very little in black zone. Sta 260 to 331, lots of movement in red and yellow zones, with failure points. Some movement in black zone. Highest area of movement with five failure points was sta 270 to 300 in red and yellow zones. Failure points: red zone, sta 232, 261, 317, major (above 4 in.), sta 241, 265, 270, minor (below 4 in.). Yellow zone, sta 271, 278, 280, 281, minor (below 4 in.).
8R1	6	1	Failure, very little movement sta 222 to 330 in red, yellow, and black zones. Some light movement sta 230 to 245 in red and yellow zones; very little in black zone. Lots of movement sta 245 to 331, with failure points in red, yellow, and black zones. Highest area of movement is sta 270 to 300 in all three zones. Failure points: red zone, sta 247, 261, major (above 4 in.), sta 308, minor (below 4 in.). Yellow zone, sta 297, minor (below 4 in.). Yellow and black zones, sta 279, major (above 4 in.).
9R1	6	1	Stable; very little movement sta 222 to 260 in red, yellow, and black zones. Some light movement in all three zones, sta 260 to 331. Highest area of movement is sta 270 to 300 in all three zones. No major holes or weak area showing up. Note: riprap was remolded and packed in place with tamper from sta 242 to 331 before test was started.
10R1	6	1	Failure; some movement sta 222 to 245 in red, yellow, and black zones. Lots of movement, with both major and minor failure points and weak

(Continued)

(Sheet 2 of 6)

Table B2 (Continued)

Test No.	Gradation No.	Curve No.	Detailed Test Results
10R1 (Cont)			spots, sta 245 to 331 in red, yellow, and black zones. Highest area of movement is sta 270 to 300 in red, yellow, and black zones. Failure points: red zone, sta 263 and 284, major (above 4 in.), sta 235, 250, 252, 270, 285, 313, minor (below 4 in.). Yellow zone, sta 276, 288, and 302, major (above 4 in.), sta 234, 271, 280, and 293, minor (below 4 in.). Black zone, sta 284, major (above 4 in.). Note: test was started at condition of riprap at end of Test 9R1.
10R2	6	1	Failure; very little movement of riprap, sta 222 to 245 in red, yellow, and black zones. Lots of movement, with failure points and weak areas, sta 245 to 331 in red, yellow, and black zones. Highest area of movement is sta 270 to 300 in red and yellow zones. Failure points: red zone, sta 250, 269, 278, 290, 291, 301, and 315, minor (below 4 in.). Yellow zone, sta 281, major (above 4 in.). Sta 264, 272, 276, 282, 289, and 291, minor (below 4 in.). Weak area: sta 260 to 262 in red zone. Note: riprap was remolded and packed in place with tamper over entire test section before test was started.
11R1	6	1	Failure; very little movement of riprap, sta 222 to 245 in red, yellow, and black zones. Some movement sta 245 to 265 in red and yellow zones. Very little in black zone. Lots of movement sta 260 to 331 in red and yellow zones; some movement in black zone. Highest area of movement, with five failure points, is sta 270 to 300 in red, yellow, and black zones. Failure points: red zone, sta 250, 267, 282, 291, and 301, minor (below 4 in.). Yellow zone, sta 264, 275, 281, and 289, major (above 4 in.). Sta 257 and 279, minor (below 4 in.). Black zone, sta 275, major (above 4 in.). Sta 279 and 293, minor (below 4 in.). Weak area: sta 260 to 263 in red zone. Note: test was started at condition of riprap at end of Test 10R2.
12R1	8	1	Stable, very little movement.
13R1	8	1	Stable, very little movement.

(Continued)

(Sheet 3 of 6)

Table B2 (Continued)

Test No.	Gradation No.	Curve No.	Detailed Test Results
14R1	8	1	Stable, very little movement sta 222 to 255 in red, yellow, and black zones. Small amount of movement sta 255 to 332 in red and yellow zones; very little in black zone.
15R1	8	1	Stable, very little movement sta 222 to 250 in red, yellow, and black zones. Some movement in red and yellow zones, sta 250 to 332; very little in black zone. Highest area of movement is sta 285 to 310 in red and yellow zones. No holes or major weak areas showing up.
16R1	8	1	Stable, very little movement sta 222 to 250 in red, yellow, and black zones. Some movement sta 250 to 332 in red, yellow, and black zones. Highest area of movement, with weak areas, sta 270 to 300 in red, yellow, and black zones. Weak areas: red zone, sta 276, 285, and 295. Yellow zone, sta 274 and 286. Black zone, sta 276, 282, and 286. Note: test was started at condition of riprap at end of Test 15R1 curve 1.
17R1	8	1	Stable, very little movement sta 222 to 250 in red, yellow, and black zones. Lots of movement sta 250 to 332 in red, yellow, and black zones. Highest area of movement, sta 270 to 300 in red, yellow, and black zones. Weak areas: red zone, sta 264, 276, 285, and 296. Yellow zone, sta 264, 274, and 286. Black zone, sta 276, 282, and 286. Note: test was started at condition of riprap at end of Test 16R1.
18R1	8	1	Stable, some movement sta 222 to 255 in red, yellow, and black zones. Lots of movement sta 255 to 332 in red, yellow, and black zones. Highest area of movement sta 270 to 300 in red, yellow, and black zones. Hole locations: yellow zone, sta 290, 6-8 in. (not solid). Black zone, sta 275, 6-8 in. (not solid). Weak areas: red zone, sta 263, 276, 285, and 296. Yellow zone, sta 263, 274, and 286. Black zone, sta 276, 282, and 286. Note: test was started at condition of riprap at end of Test 17R1 curve 1.

(Continued)

(Sheet 4 of 6)

Table B2 (Continued)

Test No.	Grada-tion No.	Curve No.	Detailed Test Results
18R2	8	1	Stable; very little movement sta 222 to 255 in red, yellow, and black zones. Some movement sta 255 to 265 in red, yellow, and black zones. Lots of movement sta 265 to 300 in red, yellow, and black zones. Some movement sta 300 to 332 in red and yellow zones. Very little in black zone. Highest area of movement sta 270 to 300 in red and yellow zones. No holes. Major weak areas: red and yellow zones, sta 273 to 280 and 284 to 290. Note: riprap was removed, remixed, and replaced from sta 265 to 310 in red, yellow, and black zones.
19R1	8	1	Stable; some movement sta 222 to 255 in red, yellow, and black zones. Very little in blue zone. Lots of movement sta 255 to 332 in red, yellow, and black zones. Very little in blue zone. Highest area of movement is sta 270 to 300 in red, yellow, and black zones. Hole locations: black zone, sta 275, 4-6 in. (not solid). Yellow zone, sta 290, 3-4 in. (not solid). Sta 270, 2-3 in. (minor). Red zone, sta 276, 1-2 in. (minor). Major weak areas: black and yellow zones, sta 274 to 277. Red, yellow, and black zones, sta 284 to 290, with the heaviest being at sta 288 in black zone. Red, yellow, and black zones, sta 294 to 299. Note: test was started at condition of riprap at end of Test 18R1 curve 1. Failure; very little movement sta 222 to 245 in red, yellow, and black zones. Some movement sta 245 to 260 in red, yellow, and black zones. Lots of movement sta 260 to 310 in red, yellow, and black zones. Some movement sta 310 to 332 in red, yellow, and black zones. Highest area of movement with three holes and major wear areas is sta 270 to 300 in red and yellow zones. Hole locations: red zone, sta 233 and 278, minor (below 4 in.). Yellow zone, sta 246 and 278 major (above 4 in.). Sta 254 and 298, minor (below 4 in.). Major weak areas: red, yellow, and black zones, sta 266, 273 to 279, 285 to 290, and 295 to 300. Note: test was started at condition of riprap at end of Test 18R2 curve 1.

(Continued)

(Sheet 5 of 6)

Table B2 (Concluded)

Test No.	Gradation No.	Curve No.	Detailed Test Results
20R1	8	1	Failure; some movement sta 222 to 255 in red, yellow, and black zones. Very little in blue zone. Lots of movement sta 255 to 332 in red, yellow, and black zones. Very little in blue zone. Highest area movement sta 270 to 300 in red, yellow, and black zones. Hole location: red zone, sta 258, major (above 4 in.), sta 287, 270, minor (below 4 in.). Yellow zone, sta 270, 288, 294, and 304, minor (below 4 in.). Black zone, sta 275, major (above 4 in.). Major weak areas: red, yellow, and black zones, sta 273 to 278, 284 to 290, 294 to 299. Red and yellow zones, sta 303 to 306. Note: test was started at condition of riprap at end of Test 19R1 curve 1.
20R2	8	1	Failure; very little movement sta 222 to 245 in red, yellow, and black zones. Some movement sta 245 to 265 in red, yellow, and black zones. Lots of movement sta 265 to 310 in red, yellow, and black zones. Some movement sta 310 to 332 in red, yellow, and black zones. Very little movement in blue zone, sta 222 to 332. Highest area of movement with failures is sta 270 to 300 in red, yellow, and black zones. Hole locations: red zone, sta 277, minor (below 4 in.). Yellow zone, sta 274, 278, 298, major (above 4 in.). Stations 271, 288, 297, minor (below 4 in.). Black zone, sta 246 and 276 major (above 4 in.). Major weak areas: red, yellow, and black zones, sta 265 to 267, 272 to 279, 285 to 290, and 295 to 300. Note: test was started at condition of riprap at end of Test 20R1 curve 1.

(Sheet 6 of 6)

Table B3

Test Results for 1V:1.5H Side Slope

Test No.	Gradation No.	Curve No.	Detailed Test Results
1R1	2	1	Stable, very little movement.
2R1	2	1	Stable, very little movement.
3R1	2	1	Stable, some light movement in red and yellow zones.
4R1	2	1	Stable, some light movement sta 222 to 255 in red and yellow zones. Moderate amount of movement sta 260 to 300 in red and yellow zones. Light movement sta 300 to 332 in red and yellow zones. Highest areas of movement sta 260 to 270 and sta 275 to 300 in red and yellow zones. No holes or major weak areas showing up. Note: test was started at condition of riprap at end of Test 3R1.
4R2	2	1	Stable; light movement sta 222 to 258 in red and yellow zones. Moderate amount of movement sta 258 to 300 in red and yellow zones. Light movement sta 300 to 332 in red and yellow zones. Highest areas of movement sta 260 to 265 and sta 275 to 300 in red and yellow zones. No holes or major weak areas showing up. Note: riprap was remolded and repainted before test was started.
5R1	2	1	Failure: light movement sta 222 to 245 in red and yellow zones. Lots of movement sta 245 to 300 in red and yellow zones. Some movement sta 300 to 332 in red and yellow zones. Very little movement in black zone, sta 222 to 332. Highest area of movement with failure points and weak areas is sta 260 to 300 in red and yellow zones. Failure points: yellow zone, sta 269, 281, 286, 295, and 298, major (above 4 in.). Sta 250, 251, 258, 277, 288, 290, 301, and 320, minor (below 4 in.). Major weak areas: yellow zone, sta 260, 269 to 270, and 280. Note: test was started at condition of riprap at end of Test 4R1 curve 1.
5R2	2	1	Stable: some movement sta 222 to 250 in red and yellow zones. Lots of movement sta 250 to 300 in red and yellow zones. Moderate amount of movement sta 300 to in red and yellow zones.

(Continued)

(Sheet 1 of 4)

Table B3 (Continued)

Test No.	Grada-tion No.	Curve No.	Detailed Test Results
5R2 (Cont)			Very little in black zone, sta 222 to 332. Highest area of movement: yellow zone; sta 250 to 252, 259 to 270, and 275 to 300. Hole locations: yellow zone, sta 290, 2-3 in. Weak areas: yellow zone, sta 251, 260, 269, 278, and 288. Note: test was started at condition of riprap at end of Test 4R2 curve 1.
6R1	2	1	Failure: moderate amount of movement sta 222 to 248 in red and yellow zones. Lots of movement sta 248 to 332 in red and yellow zones. Very little in lower third of black zone, sta 222 to 332. Highest area of movement: sta 280 to 300 in red and yellow zones. Failure points: yellow zone, sta 260, 261, 288, and 290, major (above 4 in.), sta 235, 250, 268, 274, and 278, minor (below 4 in.); red zone, sta 306, major (above 4 in.), sta 301, minor (below 4 in.). Note: test was started at condition of riprap at end of Test 5R2 curve 1.
7R1	2	1	Failure: moderate amount of movement sta 222 to 250 in red and yellow zones. Large amount of movement sta 250 to 332 in red and yellow zones. Light movement sta 222 to 332 in lower third of black zone. Highest areas of movement: yellow zone, sta 259 to 262 and 275 to 300. Failure points: yellow zone, sta 235, 285, and 290, major (above 4 in.), sta 263, 266, 268, 274, and 301, minor (below 4 in.); yellow and black zones: sta 261 and 288, major (above 4 in.); yellow and red zones, sta 263, minor (below 4 in.). Major weak areas: yellow zone, sta 268 to 270 and 277 to 278. Note: test was started at condition of riprap at end of Test 6R1 curve 1.
8R1	4	1	Stable: light movement sta 222 to 250 in red and yellow zones. Moderate movement sta 250 to 300 in red and yellow zones. Light movement sta 300 to 332 in red and yellow zones. No movement in black zone sta 222 to 332. Highest areas of movement: yellow zone, sta 260 to 290. No holes or major weak areas.

(Continued)

(Sheet 2 of 4)

Table B3 (Continued)

Test No.	Grada-tion No.	Curve No.	Detailed Test Results
9R1	4	1	Stable: movement red and yellow zones, very little sta 222 to 240, light sta 240 to 250, heavy sta 250 to 300, moderate sta 300 to 332. Black zone, no movement. White zone, very little. Highest areas of movement: yellow zone, sta 250 to 257 and 260 to 271; red zone, sta 285 to 296. Weak areas: yellow zone, sta 264, 268 to 270, and 275; red zone, sta 285 and 295. No holes showing up. Note: test was started at condition of riprap at end of Test 8R1 curve 1.
10R1	4	1	Stable: movement red and yellow zones, very little sta 222 to 240, light sta 240 to 250, heavy sta 250 to 300, moderate sta 300 to 332. Black zone, no movement. White zone, very little. Highest areas of movement: yellow zone, sta 241, 251 to 258, 260 to 271, and 275; red zone, sta 285 to 296 and 299. Weak areas: yellow zone, sta 264 to 266, 268 to 270, and 275; red zone, sta 285, 291, and 295. No holes where filter could be seen.
10R2	4	1	Stable: movement red and yellow zones, light sta 222 to 255, moderate sta 255 to 292, light sta 292 to 332; black zone no movement; white zone, very little. Highest area of movement: red and yellow zones, sta 265 to 270 and 280 to 290. Weak areas: yellow zone, sta 286. No holes where filter could be seen.
10R3	4	1	Stable: movement red and yellow zones, light sta 222 to 255 and 297 to 332, moderate sta 255 to 297; black zone, no movement; white zone, very little sta 222 to 332. Weak areas: yellow zone, sta 256, 268 to 269, 280, and 286; red zone, sta 256 and 269.
11R1	4	1	Failure: movement red and yellow zones, light sta 222 to 240, heavy sta 240 to 305, moderate sta 305 to 332; black zone, very little sta 222 to 240 and 305 to 332, some sta 240 to 305 in lower third of zone; white zone, very little. Highest area of movement: yellow zone, sta 241, 251 to 258, 261 to 270, and 275; red zone, sta 285 to 296, and 299 to 300. Failure points: yellow and black zones, sta 269, major (above 4 in.). Weak areas: yellow zone, sta 252, 256, 264 to 266, 292, and 295; red zone, sta 292 and

(Continued)

(Sheet 3 of 4)

Table B3 (Concluded)

Test No.	Gradation No.	Curve No.	Detailed Test Results
11R1 (Cont)			295. Note: test was started at condition of riprap at end of Test 10R1 curve 1.
11R2	4	1	Stable. Movement: red and yellow zones, light sta 222 to 245 and 295 to 332, moderate sta 245 to 260, heavy sta 260 to 295; black zone, very little in lower third of zone sta 222 to 332; white zone, very little. Highest area of movement: red and yellow zones, sta 268 to 290. Weak areas: yellow zone, sta 269, 280, and 286; red zone, sta 290. No holes showing up. Note: test was started at condition of riprap at end of Test 10R2 curve 1.
11R3	4	1	Stable. Movement: red and yellow zones, light to moderate sta 222 to 255, moderate sta 255 to 300, light sta 300 to 332, black zone, very little sta 222 to 332; white zone, very little sta 222 to 332. Highest areas of movement: red and yellow zones, sta 256 to 258, 268 to 270, and 295. Weak areas: yellow zone, sta 258, 269, 280, and 295. No holes where filter fabric could be seen.
12R1	4	1	Stable. Movement: red and yellow zones, some sta 222 to 255 and 297 to 332, moderate sta 255 to 297; black zone, very little sta 222 to 332; white zone, very little. Highest area of movement: red and yellow zones, sta 255 to 257, 265 to 271, and 280 to 295. Weak areas: yellow zone, sta 256, 265, 269, 277, 280, and 287; red zone, sta 256 and 290. No holes where filter fabric could be seen. Note: test was started at condition of riprap at end of Test 11R2 curve 1.
13R1	4	1	Failure. Movement: red and yellow zones, moderate sta 222 to 254 and 296 to 332, heavy sta 254 to 296; black zone, none sta 222 to 254, light sta 254 to 332 in lower third of zone; white zone, very little. Highest areas of movement: red and yellow zones, sta 254 to 257, 264 to 270, and 280 to 290. Failure points: yellow zone, sta 255, 256, and 268, major (above 4 in.). Weak areas: yellow zone, sta 265, 276, 280, and 295; red zone, sta 290. Note: test was started at condition of riprap at end of Test 12R1 curve.

(Sheet 4 of 4)

Table B4

Bottom Riprap Stability Tests

Test No.	Gradation No.	Detailed Test Results
1R1	6	Stable; no movement.
2R1	6	Stable; no movement.
3R1	6	Stable; no movement.
4R1	6	Stable; no movement.
5R1	6	Stable; no movement.
6R1	6	Stable; very little movement.
7R1	6	Failure; some movement over entire length of test section, sta 148 to 178. Failure points and location: two at sta 175 approximately 2 ft apart on channel bottom, one at sta 155. Hole size: sta 155, 6-8 in.; sta 175, 8-10 in. and 4-6 in.

Table B5

IV:2H Stability Test Results

Granular Filter Layer Test

Test No.	Gradation No.	Curve No.	Detailed Test Results
58R1	2	3	Stable; large amount of movement sta 570 to 590 in red zone and lower half of yellow zone, moderate amount of movement sta 590 to 610 in red zone; some movement in lower half of yellow zone. Highest area of movement: sta 579 to 587 in red zone and lower half of yellow zone. Weak areas: red and yellow zones, sta 570 to 572, 578, and 580 to 585. Note: movement of riprap was recorded only in area of granular filter layer (sta 570 to 610).
58R2	2	3	Stable; moderate amount of movement sta 570 to 588 to sta 610 in red and yellow zones. Large amount of movement sta 577 to 588 in red and yellow zones. Highest area of movement: sta 580 to 584 in red and yellow zones. Weak area: yellow zone, sta 575 and 578 (minor); red and yellow zones, sta 580 to 584 (major). Note: in major weak area sta 580 to 584 there were several small holes approximately 2 to 4 in. in diameter where granular filter layer can be seen. Total protection was not lost because these holes are not solid continuous breaks in gradation No. 2 that was placed on top of 1-in. granular filter layer, which offers more protection from total failure. There was very little movement of granular filter layer.
58R3	2	3	Stable; moderate amount of sta 570 to 595 in red and yellow zones; light movement sta 595 to 610 in red and yellow zones. Highest area of movement: sta 580 to 592 in red zone. Weak areas: red zone, sta 571, 582 to 584, 586, and 592; yellow zone, sta 584. Note 1: Riprap was removed, reshaken, and remixed and placed back on top of 1-in. granular filter layer, sta 570 to 595. Sta 595 to 610 was not removed. Note 2: movement of riprap was recorded only in area of granular filter layer (sta 570 to 610).
59R1	2	3	Stable; moderate amount of movement sta 570 to 610 in red and yellow zones. Highest area of movement: sta 580 to 590 in red and yellow

(Continued)

(Sheet 1 of 3)

Table B5 (Continued)

Test No.	Gradation No.	Curve No.	Detailed Test Results
59R1 (Cont)			zones. No holes or major weak areas showing up. Note: movement of riprap was recorded only in area of granular filter layer (sta 570 to 610).
60R1	2	3	Failure: moderate amount of movement sta 570 to 578 in red and yellow zones. Large amount of movement sta 578 to 590 in red and yellow zones. Some movement sta 590 to 610 in red and yellow zones. Highest area of movement: sta 579 to 589 in yellow zone. Failure point: yellow zone, sta 579 to 589 (major) 2 ft wide by 10 ft long. Weak areas: yellow zone, sta 571 and 574. Note 1: test was started at condition of riprap at end of test 58R2 curve 3. Note 2: Movement of riprap was recorded only in area of granular filter layer (sta 570 to 610). Note 3: failure first occurred at sta 579 in yellow zone 25 hr into test where filter fabric could be seen. Hole was approximately 6 in. in diameter. All gradation No. 2 and granular filter layer had eroded away to filter fabric.
60R2	2	3	Stable; large amount of movement sta 570 to sta 595 in red and yellow zones. Moderate amount sta 595 to 610 in red and yellow zones. Highest areas of movement: red and yellow zones, sta 570 to 575 and 582 to 595. Weak areas: red and yellow zones, sta 570 to 572, 575, 583, 585, and 595. No holes where filter fabric can be seen. Note 1: test was started at condition of riprap at end of Test 58R3 curve 3. Note 2: movement of riprap was recorded only in area of granular filter layer (sta 570 to 610).
61R1	2	3	Stable; large amount of movement sta 570 to sta 596 in red and yellow zones. Moderate amount of movement sta 596 to 610 in red and yellow zones. Highest areas of movement: red and yellow zones, sta 570 to 573 and 582 to 595. Major weak areas: red and yellow zones, sta 570 to 572; yellow zone, sta 582 to 583 and 593. In these major weak areas, protection has not eroded through granular filter layer; but very little of gradation No. 2 remains in area. Minor weak areas: red and yellow zones, sta 575

(Continued)

(Sheet 2 of 3)

Table B5 (Concluded)

Test No.	Gradation No.	Curve No.	Detailed Test Results
61R1 (Cont)			and 585 to 591; yellow zone, sta 578 to 579 and 607. Note 1: test was started at condition of riprap at end of Test 60R2 curve 3. Note 2: movement of riprap was recorded only in area of granular filter layer (sta 570 to 610). Note 3: stable but very close to failure.
62R1	2	3	Failure: large amount of movement in red and zones with failures and major weak areas sta 570 to 597. Some movement in black zone, mostly sta 581 to 584. Moderate amount of movement sta 597 to 610. Highest area of movement: sta 580 to 597 in yellow zone. Failure points: yellow zone, sta 570 to 572 (major) 18 in. long by 6 in. wide; yellow zone and lower edge of black zone, sta 581 to 584 (major) 3 ft long by 1 ft wide. Major weak areas: yellow zone, sta 577 to 578 and 590 to 594. Note 1: test was started at condition of riprap at end of Test 61R1 curve 3. Note 2: movement of riprap was recorded only in area of granular filter layer (sta 570 to 610).

(Sheet 3 of 3)

APPENDIX C: NOTATION

C	Generic coefficient
C_{sm}	Modified Shields coefficient
C_t	Ratio of stability coefficients for thickness
d	Flow depth
D_r	Characteristic particle size
D, D_{90}, D_{50}, etc.	Particle size of which a certain percent is finer by weight
D_{85},D_{15}	Gradation uniformity
g	Gravitational acceleration
K	Tractive force ratio for side slope
n	Manning's roughness coefficient
N	Relative layer thickness
Q	Discharge
R	Center-line radius of the bend
S	Energy slope; channel slope
V	Depth-averaged flow velocity
V_y	Velocity at distance y above the bottom
W	Water-surface width
γ_s	Unit weight of stone
γ_w	Unit weight of water
θ	Angle of side slope with horizontal
τ_b	Tractive force imposed by flowing water; bed shear stress
τ_c	Critical tractive force for given particle size on bottom
τ_s	Critical tractive force for particle on side slope

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